

Table 5

HALOGENATED

Follow-up Requirements for Halogenated Group 2 Vents For Calculation-Based TRE Cut-Off = 1.5		
TRE Confidence Interval	Follow-Up Requirement	No. of Vents Affected
Minimum > 1.5	None - Clearly Group 2	3
Maximum < 1.5	Testing - False Indication as Group 1	0
Minimum < 1.5 and Maximum > 1.5	Testing as Indicated by TRE Estimate	4

NON-HALOGENATED

Follow-up Requirements for Non-Halogenated Group 2 Vents For Calculation-Based TRE Cut-Off = 3		
TRE Confidence Interval	Follow-Up Requirement	No. of Vents Affected
Minimum > 3	None - Clearly Group 2	7
Maximum \leq 3	Testing - False Indication as Group 1	5
Minimum < 3 and Maximum > 3	Testing as Indicated by TRE Estimate	10

APPENDIX A

Variance Formula Derivation

Introduction

TRE is a calculated quantity from a mathematical combination of four observed quantities or variables. Inaccuracies in the measurements or estimations of the values of the variables will be propagated through the TRE formula to cause inaccuracies in the TRE value. The following is a formula derivation to calculate the quantity of inaccuracy in TRE that is propagated from inaccuracies in the variables.

Formula Derivation

The variance of a linear combination of independent variables is calculated from the formula

$$VAR [\bar{x}] = \sum_{i=1}^n \left[\frac{\partial \bar{x}}{\partial \chi_i} \right]^2 VAR[\chi_i]$$

Where

\bar{x} is the vector of independent variables

χ_i is the i^{th} independent variable and

(VAR () is the variance of the argument)

The TRE formula from Page 368 of the December 24, 1991, draft HON is

$$TRE = \frac{1}{E_{HAP}} [a + b(Q_p) + c(H_T) + d(E_{TOC})]$$

Where

E_{HAP} = kilograms per hour

Q_s = std. cu. meters per minute

H_T = megaJoules per std. cu. meter

E_{TOC} = kilograms per hour

a, b, c, d - coefficients assigned by the draft rule

Linearizing the TRE formula gives

$$\ln TRE = \ln[a + bQ_s + cH_T + dE_{TOC}] - \ln E_{HAP}$$

Applying the variance formula to both sides of the linearized TRE formula results in the following implicit equation for VAR(TRE):

$$\frac{1}{TRE^2} VAR (TRE) = \frac{b^2 VAR (Q_s)}{(a + bQ_s + cH_T + dE_{TOC})^2} + \frac{c^2 VAR (H_T)}{(a + bQ_s + cH_T + dE_{TOC})^2}$$

$$+ \frac{d^2 VAR (E_{TOC})}{(a + bQ_s + cH_T + dE_{TOC})^2} + \frac{1}{E_{HAP}^2} VAR (E_{HAP})$$

Solving explicitly for VAR(TRE) gives

$$VAR (TRE) = \frac{b^2 TRE^2}{(a + bQ_s + cH_T + dE_{TOC})^2} VAR(Q_s) + \frac{c^2 TRE^2}{(a + bQ_s + cH_T + dE_{TOC})^2} VAR(H_T)$$

$$+ \frac{d^2 TRE^2}{(a + bQ_s + cH_T + dE_{TOC})^2} VAR(E_{TOC}) + \frac{TRE^2}{E_{HAP}^2} VAR(E_{HAP})$$

Rearranging the TRE equation provides the following equivalence:

$$(E_{HAP}) (TRE) = a + bQ_s + cH_T + dE_{TOC}$$

Substituting this equivalence into the VAR(TRE) equation simplifies the formula to the following:

$$VAR(TRE) = \frac{1}{E_{HAP}^2} [b^2 VAR(Q_s) + c^2 VAR(H_T) + d^2 VAR(E_{TOC}) + TRE^2 VAR(E_{HAP})]$$

Reference: George E. P. Box, William G. Hunter, J. Stuart Hunter, Statistics For Experimentors. An Introduction to Design, Data Analysis, and Model Building, (John Wiley & Sons, New York, 1978)

Appendix B - Table A-1

Vent Data From Draft BID
Non-Halogenated Vents

Table No.	Product	Flow Rate (scfm)	Heat Content (Btu/scf)	Temp (oP)	Oxygen Content (vol %)	Total VOC Emission Rate (Hg/yr)	VOC Composition (wt %)	HAP Emission Rate (Hg/yr)	HAP Composition (wt %)
2-3	Methyl Methacrylate	156	221	111	14.90	1850	35.5	1520	34.7
2-3	Dimethyl Terephthalate	51.7	2180	100	7.82	900	66.2	290	22.2
2-2	Ethylene Oxide	27200	5.91	270	4.30	1780	0.07	1770	0.07
2-2	Acrylonitrile	57000	25.9	112	4.49	12400	0.65	2570	0.12
2-2	Maleic Anhydride	36600	10.1	100	13.30	1720	0.27	1580	0.25
2-5	Air Oxidation	17400	15.9	90	6.07	1560	1.34	926	0.2
2-5	Distillation V	52.7	135	100	0.00	682	9.53	134	5
2-3	Acetic Acid	353	344	111	2.50	1410	10.9	180	1.4
2-2	Phthalic Anhydride	61000	2.98	113	12.40	2470	2.77	1810	2.53
2-3	Butadiene	5.22	1450	111	0.00	110	50.4	110	50.4
2-4	Styrene	2330	282	97.4	0.18	1730	13.4	326	13.3
2-3	Methanol	74.2	1180	111	6.25	1920	96.4	115	22.7
2-2	Formaldehyde	5020	1.37	95	6.07	239	0.05	215	0.07
2-4	Nitrobenzene	13	434	74.8	0.08	75.5	23.2	75.5	23.2
2-3	Vinyl Acetate	10.3	451	111	0.00	73	30.9	73	30.9
2-5	Distillation NW	11.2	560	99.2	0.00	198	52.2	60.9	24.6
2-3	Cyclohexanone/cyclohexane	38.6	58.6	89.2	0.00	69.2	2	45.5	1.74
2-4	Ethylbenzene	12.3	121	97.4	0.18	32	17.3	38.4	15.9
2-5	Dehydrogenation	557	283	68	0	322	17.8	60.6	12.3
2-5	Nitration	418	6.76	75	0.18	39	13.7	38	13.7
2-3	Methyl Ethyl Ketone	3.55	1750	111	3.02	24.2	59.3	19.9	12.3
2-3	Ethyl Acrylate	246	47.7	99.2	4.97	1830	1.62	20.5	0.23
2-2	Acetaldehyde	9320	16.3	52	0.95	61	0.03	60	0.03
2-4	Ethylene Glycol Mono	3	102	74.8	0.18	372	13.5	13.2	7.81
2-3	Ethylacetate	1.5	335	111	4.49	13.5	25.7	13.5	25.7
2-2	Terephthalic Acid	16300	7.59	92	5.32	1170	0.18	115	0.03
2-5	Hydrogenation	729	1230	74.8	0.18	9510	13.5	13.2	7.31
2-4	Benzene	1230	205	74.8	0.18	33	13.5	13.2	7.81
2-5	Catalytic Reforming	1290	205	74.8	0.18	33	13.5	13.2	7.31
2-3	Nitrobenzene	1.5	352	89.2	1.10	7.15	9.6	7.15	3.6
2-5	Hydrodimerization	1080	70	74.8	0.18	107	13.5	13.2	7.31
2-4	Adiponitrile	1020	70	74.8	0.18	107	13.5	13.2	7.31
2-5	Esterification	14.9	102	74.8	0.18	61.2	12.1	5.91	14.4
2-5	Alkylation	1.79	121	63	0.00	4.45	15.3	4.45	17.3
2-5	Condensation	57.7	1070	69	0	476	13.5	5.19	7.81
2-3	Terephthalic Acid	1.25	114	111	0.00	3.81	6.59	3.81	6.53
2-5	Generic Reaction	260	209	68	0	138	3.38	4.6	5.21
2-3	Aniline	0.03	3230	89.2	0.74	1.59	37	1.59	37
2-5	Hydroformylation	350	714	71.5	0	1920	10.6	4.84	6.14
2-3	Ethylbenzene	2.34	322	111	0.00	1.33	0.93	1.33	0.93
2-5	Oxidation	5510	2.38	90	0	139	8.05	3.55	4.65
2-5	Hydrolysis	39	0	60	0.18	0.4	13.5	0.4	7.31

NOTES: Table No. references are to Tables Nos. in Draft BID.

Appendix B - Table A-1

Vent Data From Unit 511
Non-Halogenated Vents

Table No.	Product	Flow Rate (scfa)	Heat Content (Btu/scf)	Temp (°F)	Oxygen Content (vol %)	Total VOC Emission Rate (Mg/yr)	VOC Composition (wt %)	HAP Emission Rate (Mg/yr)	HAP Composition (wt %)
2-3	Formaldehyde	1.19	9	100	0.00	0.3	1.0	0.3	1.0
2-4	Dinitrotoluene	322	0	74.9	0.18	0.4	13.5	0.4	13.5
2-5	Sulfonation	1550	0	74.9	0.18	0.4	13.5	0.4	13.5
2-4	Vinyl Acetate	7	407	63	0.18	0.4	12.5	0.2	6.25
2-5	Oxyacetylation	7	407	63	0.18	0.4	12.5	0.2	6.25
2-4	Caprolactam	0	0	58	0.00	0	0	0	0
2-5	Carbonylation	19000	295	74.9	0.18	292	0.5	0	0
2-4	Linear Alkylbenzene	0	0	58	0.00	0	0	0	0
2-3	Styrene	0	0	111	0.00	0	0	0	0
2-4	Methyl Ethyl Ketone	0	0	58	0.00	0	0	0	0
2-3	Phenol	0	0	111	0.00	0	0	0	0
2-4	Cyclohexane	0	0	58	0.00	0	0	0	0
2-3	Mesityl Oxide	0	0	111	0.00	0	0	0	0
2-4	Phenol/Acetone	0	0	0	0.00	0	0	0	0
2-3	Ethylene Glycol	25.8	0	100	0.00	0	0	0	0
2-4	Carbon Disulfide	0	0	58	0.00	0	0	0	0
2-3	Ethanolamines	11.9	0	100	10.50	0	0	0	0
2-3	Aniline	0	0	58	0.00	0	0	0	0
2-3	Cyclohexane	0	0	111	0.00	0	0	0	0
2-3	Cumene	0	0	111	0.00	0	0	0	0
2-4	Dimethyl Terephthalate	0	0	58	0.00	0	0	0	0
2-4	Nonylphenol	0	0	58	0.00	0	0	0	0
2-4	Bisphenol -A	0	0	58	0.00	0	0	0	0
2-3	Carbon Disulfide	0	0	111	0.00	0	0	0	0
2-4	Ethylene Glycol	0	0	58	0.00	0	0	0	0
2-3	Caprolactam	0	0	110	0.00	0	0	0	0
2-4	MPEG	0	0	58	0.00	0	0	0	0
2-4	Cumene	0	0	58	0.00	0	0	0	0
2-3	Allyl Alcohol	0	0	111	0.00	0	0	0	0
2-3	Adiponitrile	75	0	99.2	0.00	0	0	0	0

Appendix B - Table B-2

Vent Data From Draft III
Halogenated Vents

Table No.	Product	Flow Rate (scfm)	Heat Content (Btu/scf)	Temp (oF)	Oxygen Content (vol %)	Total VOC Emission Rate (Mg/yr)	VOC Composition (wt %)	HAP Emission Rate (Mg/yr)	HAP Composition (wt %)
2-4	Vinylidene Chloride	10	600	90	0.18	163	0	163	0
2-5	Dehydrohalogenation	5	496	79	0.69	31.5	0	31.5	0
2-3	Chlorobenzene	2.13	396	59.27	12.54	49.6	10.3	49.6	10.3
2-4	Chlorobenzene	55	0	74.3	0.13	15.9	13.5	13.2	7.31
2-5	Oxyhalogenation	394	713	74.2	5.13	2370	13.5	13.2	7.31
2-4	Methyl Chloride	26	586	74.2	0.13	3.34	13.5	3.24	7.31
2-4	Ethylene Dichloride	114	752	74.3	0.12	132	13.5	3.2	7.31
2-3	Perchloroethylene	2.27	13	111	0.00	3.34	2	3.34	2
2-5	Halogenation	347	36.7	63	0	69.3	13.5	2.73	7.31
2-5	Hydrohalogenation	4.2	333	68	0	71	13.5	3.26	10.7
2-3	Trichlorofluoromethane	0	0	111	0.00	0	0	0	0
2-4	Ethanolamines	0	0	74	0.00	0	10	0	10
2-3	Trichloroethylene	0	0	111	0.00	0	0	0	0
2-4	Freon 11, 12, 113, 114	0	0	68	0.00	0	0	0	0
2-3	Trichloroethane	0	0	111	0.00	0	0	0	0
2-3	Dichlorodifluoromethane	0	0	111	0.00	0	0	0	0
2-3	Vinylchloride	0	0	111	0.00	0	0	0	0
2-4	Freon	0	0	68	0.00	0	0	0	0
2-3	Chlorodifluoromethane	0	0	111	0.00	0	0	0	0
2-3	Carbon Tetrachloride	0	0	111	0.00	0	0	0	0
2-3	Allyl Chloride	0	0	100	0.00	0	0	0	0
2-4	Allyl Chloride	0	0	68	0.00	0	0	0	0
2-4	Freon - 12	0	0	68	0.00	0	0	0	0

Appendix B - Table B-1

Input Variables With Correct
Units for TRE Calculation
Non-Halogenated Vents

Table No.	Product	Flow Rate (scmm)	Heat Content (MJ/scmm)	Total VOC Emission Rate (Kg/hr)	HAP Emission Rate (Kg/hr)
2-3	Methyl Methacrylate	1.117152	4.233797	211.1952	170.7118
2-3	Dimethyl Terephthalate	1.717158	81.22026	102.7307	70.1050
2-2	Ethylene Oxide	770.2224	0.220138	203.1963	202.054
2-2	Acrylonitrile	1614.069	0.981956	1417.325	283.373
2-2	Malic Anhydride	1019.412	0.376295	196.3470	191.780
2-5	Air Oxidation	192.7153	0.629643	173.0821	94.2922
2-5	Distillation W.	1.492305	5.029695	77.85388	15.2968
2-2	Acetic Acid	10.13748	12.81640	160.9539	20.5479
2-1	Phthalic Anhydride	1727.337	0.111025	281.9634	206.621
2-3	Butadiene	0.176131	54.02265	12.55707	12.5570
2-1	Styrene	81.83613	10.50647	197.4885	37.2146
2-3	Methanol	2.101121	43.96326	219.1780	13.2420
2-2	Formaldehyde	142.1513	0.051042	27.28310	24.5433
2-4	Nitrobenzene	0.368121	16.16953	8.618721	8.61872
2-3	Vinyl Acetate	0.308655	16.80290	8.333333	8.33333
2-5	Distillation NV	0.334140	20.86392	22.60273	6.95205
2-3	Cyclohexanone/cyclohexane	1.093036	2.183260	7.899543	5.19406
2-4	Ethylbenzene	0.362457	4.508097	3.652968	4.38356
2-5	Dehydrogenation	15.77256	10.54373	36.75799	6.91780
2-3	Nitration	11.83650	0.251857	4.337899	4.33789
2-3	Methyl Ethyl Ketone	0.100525	65.19975	9.680365	2.27169
2-3	Ethyl Acrylate	6.965982	1.777158	208.9041	2.34018
2-2	Acetaldehyde	280.9046	0.607289	6.963470	6.84931
2-4	Ethylene Glycol Mono	0.226536	3.800214	42.46575	1.50684
2-3	Ethylacetate	0.042475	34.83529	1.541095	1.54109
2-2	Terephthalic Acid	1311.077	0.282780	133.5616	13.1278
2-5	Hydrogenation	20.64309	45.82611	1085.616	1.50684
2-4	Benzene	36.52893	7.637685	3.767123	1.50684
2-5	Catalytic Reforming	36.52893	7.637685	3.767123	1.50684
2-3	Nitrobenzene	0.042475	13.11446	0.816210	0.81621
2-5	Hyrodimerization	30.58236	2.60799	12.21461	1.50684
2-4	Adiponitrile	30.58236	2.60799	12.21461	1.50684
2-5	Esterification	0.421923	3.800214	6.986301	0.66324
2-5	Alkylation	0.050687	4.508097	0.507990	0.50799
2-5	Condensation	1.633890	39.86499	54.33789	0.59240
2-3	Terephthalic Acid	0.035679	4.247298	0.434931	0.43493
2-5	Generic Reaction	7.86242	7.786713	15.75342	0.5251
2-3	Aniline	0.000849	120.3401	0.181506	0.1815
2-5	Hydroformylation	24.06945	26.60149	226.0273	0.5525
2-3	Ethylbenzene	0.083251	11.99675	0.151826	0.1518
2-5	Oxidation	156.0266	0.088671	15.86757	0.4052
2-5	Hydrolysis	2.803383	0	0.045662	0.0456
2-3	Formaldehyde	0.033697	0.335313	0.031246	0.0342
2-4	Dinitrotoluene	23.27657	0	0.045662	0.0456

Appendix B - Table B-1

Input Variables With Correct
Units for TRE Calculation
Non-Halogenated Vents

Table No.	Product	Flow Rate (scmm)	Heat Content (MJ/scm)	Total VOC Emission Rate (Kg/hr)	HAP Emission Rate (Kg/hr)
2-5	Sulfonation	52.66962	0	0.045662	0.04566
2-4	Vinyl Acetate	0.198219	15.16359	0.045662	0.02283
2-5	Oxyacetylation	0.198219	15.16359	0.045662	0.02283
2-4	Caprolactam	0	0	0	
2-5	Carbonylation	538.023	10.99081	34.01826	
2-4	Linear Alkylbenzene	0	0	0	
2-3	Styrene	0	0	0	
2-4	Methyl Ethyl Ketone	0	0	0	
2-3	Phenol	0	0	0	
2-4	Cyclohexane	0	0	0	
2-3	Mesityl Oxide	0	0	0	
2-4	Phenol/Acetone	0	0	0	
2-3	Ethylene Glycol	0.730578	0	0	
2-4	Carbon Disulfide	0	0	0	
2-3	Ethanolamines	0.336972	0	0	
2-4	Aniline	0	0	0	
2-3	Cyclohexane	0	0	0	
2-3	Cumene	0	0	0	
2-4	Dimethyl Terephthalate	0	0	0	
2-4	Nonylphenol	0	0	0	
2-4	Bisphenol -A	0	0	0	
2-3	Carbon Disulfide	0	0	0	
2-4	Ethylene Glycol	0	0	0	
2-3	Caprolactum	0	0	0	
2-4	MTBE	0	0	0	
2-4	Cumene	0	0	0	
2-3	Allyl Alcohol	0	0	0	
2-3	Adiponitrile	2.123775	0	0	

Appendix B - Table B-2

Input Variables With Correct
Units for TRE Calculation
Halogenated Vents

Table No.	Product	Flow Rate (scmm)	Heat Content (MJ/scm)	Total VOC Emission Rate (Kg/hr)	HAP Emission Rate (Kg/hr)
2-4	Vinylidene Chloride	0.28317	22.3542	18.60730	18.6073
2-5	Dehydrohalogenation	0.141585	22.3542	9.303652	9.30365
2-3	Chlorobenzene	0.231916	14.75377	5.662100	5.66210
2-4	Chlorobenzene	1.557435	0	1.815068	1.50684
2-5	Oxyhalogenation	8.608368	26.56424	339.0410	1.50684
2-4	Methyl Chloride	0.56634	18.6285	0.952054	0.95205
2-4	Ethylene Dichloride	3.228138	28.01726	20.77625	1.08447
2-3	Perchloroethylene	0.064279	0.670626	0.381278	0.38127
2-5	Halogenation	23.98449	1.367331	7.968036	0.55639
2-5	Hydrohalogenation	0.118931	33.27050	8.105022	0.25799
2-3	Trichlorofluoromethane	0	0	0	
2-4	Ethanolamines	0	0	0	
2-3	Trichloroethylene	0	0	0	
2-4	Freon 11, 12, 113, 114	0	0	0	
2-3	Trichloroethane	0	0	0	
2-3	Dichlorodifluoromethane	0	0	0	
2-3	Vinylchloride	0	0	0	
2-4	Freon	0	0	0	
2-3	Chlorodifluoromethane	0	0	0	
2-3	Carbon Tetrachloride	0	0	0	
2-3	Allyl Chloride	0	0	0	
2-4	Allyl Chloride	0	0	0	
2-4	Freon - 12	0	0	0	

APPENDIX B - TABLE B

Notes: Conversions applied to EPA data

$$\text{Flowrate (scmm)} = \text{Flowrate (scfm)} \times (0.3048 \text{ m/ft})^3$$

$$\text{Emission Rate (Kg/hr)} = \text{Emission Rate (Mg/yr)} \times (1000 \text{ Kg/Mg}) \times (1 \text{ yr}/8760 \text{ hr})$$

$$\text{Heat Content (MJ/m}^3\text{)} = \text{Heat Content (BTU/ft}^3\text{)} \times (1 \text{ ft}/0.3048\text{m})^3 \times \\ (1.055 \text{ KJoule/BTU}) \times (1 \text{ MJ}/1000 \text{ KJoule})$$

Appendix B - Table C-1
Variable Variance Estimates
Non-Halogenated Vents

No.	Product	HAP			TEC			HT			QS		
		e Hap	Sig Hap	Var (eHap)	eTOC	Sig TOC	Var (eTOC)	eHT	Sig HT	Var (eHT)	eQS	Sig QS	Var (eQS)
2-3	Methyl Methacrylate	17.3516	5.7839	33.4531	21.1187	7.0396	49.5555	16.47	5.4900	30.1401	0.8835	0.2945	0.0867
2-3	Dimethyl Terephthalate	2.9824	0.9941	0.9883	10.2740	3.4247	11.7283	162.44	54.1467	2931.8615	0.2832	0.0944	0.0089
2-2	Ethylene Oxide	1.4144	0.4715	0.2223	1.4224	0.4741	0.2248	2.2	0.7333	0.5378	154.04	51.3479	2636.6034
2-2	Acrylonitrile	35.2329	11.7443	137.9286	92.0091	30.6697	940.6305	1.93	0.6433	0.4139	322.81	107.6040	11578.6280
2-2	Maleic Anhydride	4.9863	1.6621	2.7626	5.3014	1.7671	3.1228	0.75	0.2500	0.0625	203.88	67.9604	4618.6205
2-5	Air Oxidation	7.5434	2.5145	6.3225	265.7943	88.5981	7849.6233	1.26	0.4200	0.1764	98.542	32.8475	1078.9604
2-5	Distillation V	6.1187	2.0396	4.1598	16.3387	5.4462	29.6615	10.06	3.3533	11.2448	0.2832	0.0944	0.0089
2-3	Acetic Acid	29.3542	9.7847	95.7410	29.5337	9.8446	96.9155	25.63	8.5433	72.9885	2.0275	0.6758	0.4568
2-2	Phthalic Anhydride	160.1713	53.3904	2850.5384	203.5837	67.8612	4605.1470	1.11	0.3700	0.1369	345.46	115.1552	13260.7124
2-3	Butadiene	1.2557	0.4186	0.1752	1.2557	0.4186	0.1752	108.05	36.0167	1297.2003	0.2832	0.0944	0.0089
2-4	Styrene	5.5962	1.8654	3.4797	21.4662	7.1554	51.1997	21.01	7.0033	49.0467	16.367	5.4557	29.7647
2-3	Methanol	1.1667	0.3889	0.1512	21.9178	7.3059	53.3767	87.93	29.3100	859.0761	0.2832	0.0944	0.0089
2-2	Formaldehyde	0.1718	0.0573	0.0033	0.2183	0.0728	0.0053	0.51	0.1700	0.0289	28.430	9.4767	89.8078
2-4	Nitrobenzene	0.7430	0.2477	0.0613	0.7430	0.2477	0.0613	32.34	10.7800	116.2084	0.2832	0.0944	0.0089
2-3	Vinyl Acetate	0.8333	0.2778	0.0772	0.8333	0.2778	0.0772	33.61	11.2033	125.5147	0.2832	0.0944	0.0089
2-5	Distillation HV	0.5652	0.1884	0.0355	2.2603	0.7534	0.5677	41.73	13.9100	193.4881	0.2832	0.0944	0.0089
2-3	Cyclohexanone/cyclohexane	5.9702	1.9901	3.9604	7.8995	2.6332	6.9336	4.37	1.4567	2.1219	0.2832	0.0944	0.0089
2-4	Ethylbenzene	0.5514	0.1838	0.0338	0.4104	0.1368	0.0187	9.02	3.0067	9.0400	0.2832	0.0944	0.0089
2-5	Dehydrogenation	1.0809	0.3603	0.1298	4.1301	1.3767	1.8953	21.09	7.0300	49.4209	3.1545	1.0515	1.1057
2-5	Nitration	0.6333	0.2111	0.0446	0.6333	0.2111	0.0446	2.52	0.8400	0.7056	2.3673	0.7891	0.6227
2-3	Methyl Ethyl Ketone	0.3694	0.1231	0.0152	0.9680	0.3227	0.1041	130.4	43.4667	1889.3511	0.2832	0.0944	0.0089
2-3	Ethyl Acrylate	0.1942	0.0647	0.0042	257.9063	85.9688	7390.6288	3.55	1.1833	1.4003	1.3932	0.4644	0.2157
2-2	Acetaldehyde	0.0205	0.0068	0.0000	0.0209	0.0070	0.0000	1.21	0.4033	0.1627	56.180	18.7269	350.6955
2-4	Ethylene Glycol Mono	0.3859	0.1286	0.0165	6.2912	2.0971	4.3977	7.6	2.5333	6.4178	0.2832	0.0944	0.0089
2-3	Ethylacetate	0.1541	0.0514	0.0026	0.1541	0.0514	0.0026	69.67	23.2233	539.3232	0.2832	0.0944	0.0089

2-2	Terephthalic Acid	0.0394	0.0131	0.0002	2.4041	0.8014	0.6422	2.83	0.9433	0.8899	262.21	87.4047	7639.5758
2-5	Hydrogenation	0.3859	0.1286	0.0165	160.8321	53.6107	2874.1071	91.65	30.55	933.3025	4.1286	1.3762	1.8939
2-4	Benzene	0.3859	0.1286	0.0165	0.5581	0.186033	0.0346084	15.28	5.093333	25.942044	7.3057	2.4352	5.9304
2-5	Catalytic Reforming	0.3859	0.1286	0.0165	0.5581	0.186033	0.0346084	15.28	5.093333	25.942044	7.3057	2.4352	5.9304
2-3	Nitrobenzene	0.1700	0.0567	0.0032	0.0177	0.0059	0.0000348	26.23	8.743333	76.445877	0.2832	0.0944	0.0089
2-5	Hydrodimerization	0.3859	0.1286	0.0165	1.8096	0.6032	0.3638502	5.22	1.74	3.0276	6.1164	2.0388	4.1567
2-4	Adiponitrile	0.3859	0.1286	0.0165	1.8096	0.6032	0.3638502	5.22	1.74	3.0276	6.1164	2.0388	4.1567
2-5	Esterification	0.0921	0.0307	0.0009	0.8679	0.2893	0.0836944	7.6	2.533333	6.4177777	0.2832	0.0944	0.0089
2-5	Alkylation	0.0571	0.0190	0.0004	0.0571	0.019033	0.0003622	9.02	3.006666	9.0400444	0.2832	0.0944	0.0089
2-5	Condensation	0.1517	0.0506	0.0026	8.0501	2.683366	7.2004566	79.73	2.7666	706.31921	0.2832	0.0944	0.0089
2-3	Terephthalic Acid	0.1320	0.0440	0.0019	0.132	0.044	0.001936	8.49	2.83	8.0089	0.2832	0.0944	0.0089
2-5	Generic Reaction	0.2016	0.0672	0.0045	3.7598	1.253266	1.5706773	15.57	5.19	26.9361	1.4725	0.4908	0.2409
2-3	Aniline	0.0182	0.0061	0.0000	0.0182	0.006066	0.0000368	240.68	80.22666	6436.3180	0.0085	0.0028	0.0000
2-5	Hydroformylation	0.1800	0.0600	0.0036	42.6467	14.21556	202.08233	53.2	17.73333	314.47111	4.8139	1.6046	2.5748
2-3	Ethylbenzene	0.0141	0.0047	0.0000	0.0141	0.0047	0.0000220	23.99	7.996666	63.946677	0.2832	0.0944	0.0089
2-5	Oxidation	0.1743	0.0581	0.0034	3.9423	1.3141	1.7268588	0.89	0.296666	0.0880111	31.205	10.4017	108.1961
2-5	Hydrolysis	0.0117	0.0039	0.0000	0.0068	0.002266	0.0000051	0.37	0.123333	0.0152111	0.2832	0.0944	0.0089
2-3	Formaldehyde	0.0527	0.0176	0.0003	0.0527	0.017566	0.0003085	3.35	1.116666	1.2469444	0.2832	0.0944	0.0089
2-4	Dinitrotoluene	0.0068	0.0023	0.0000	0.0068	0.002266	0.0000051	0.37	0.123333	0.0152111	4.6553	1.5518	2.4080
2-5	Sulfonation	0.0068	0.0023	0.0000	0.0068	0.002266	0.0000051	0.37	0.123333	0.0152111	10.533	3.5113	12.3292
2-4	Vinyl Acetate	0.0073	0.0024	0.0000	0.0073	0.002433	0.0000059	30.33	10.11	102.2121	0.2832	0.0944	0.0089
2-5	Oxyacetylation	0.0073	0.0024	0.0000	0.0073	0.002433	0.0000059	30.33	10.11	102.2121	0.2832	0.0944	0.0089

Appendix B - Table C-2
 Variable Variance Estimates
 Halogenated Vents

Table No.	Product	HAP			TOC			HT			QS		
		e Hap	Sig Hap	Var (eHap)	eTOC	Sig TOC	Var (eTOC)	eHT	Sig HT	Var (eHT)	eQS	Sig QS	Var (eQS)
2-4	Vinylidene Chloride	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	44.71	14.9033	222.1093	0.2832	0.0944	0.0089
2-5	Dehydrohalogenation	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	44.71	14.9033	222.1093	0.2832	0.0944	0.0089
2-3	Chlorobenzene	1.0389	0.3463	0.1199	1.0389	0.3463	0.1199	29.51	9.8367	96.7600	0.2832	0.0944	0.0089
2-4	Chlorobenzene	0.3946	0.1315	0.0173	0.2689	0.0896	0.0080	0.37	0.1233	0.0152	0.2832	0.0944	0.0089
2-5	Oxyhalogenation	0.3859	0.1286	0.0165	50.2283	16.7428	280.3202	53.13	17.7100	313.6441	1.7217	0.5739	0.3294
2-4	Methyl Chloride	0.2438	0.0813	0.0066	0.141	0.047	0.002209	37.26	12.42	154.2564	0.2832	0.0944	0.0089
2-4	Ethylene Dichloride	0.2777	0.0926	0.0086	3.078	1.026	1.052676	56.03	18.67666	348.81787	0.6456	0.2152	0.0463
2-3	Perchloroethylene	0.3813	0.1271	0.0162	0.3813	0.1271	0.0161544	1.34	0.446666	0.1995111	0.2832	0.0944	0.0089
2-5	Halogenation	0.1681	0.0560	0.0031	1.1804	0.393466	0.1548160	2.73	0.91	0.8281	4.7969	1.5990	2.5567
2-5	Hydrohalogenation	0.0482	0.0161	0.0003	1.2007	0.400233	0.1601867	66.54	22.18	491.9524	0.2832	0.0944	0.0089

APPENDIX B - TABLE C

Notes - Estimation Formulas

$$\text{Error Estimates in High Range} = \frac{\text{Error Percentage} \times \text{Variable Value}}{100}$$

$$\text{Error Estimates in Intermediate Range} = \text{Error Magnitude} \\ [= \text{Variable Value} \times 10 \text{ for Heat Content}]$$

$$\text{Error Estimates in Low Range} = \text{Variable Value} \times 10 \\ [= \text{Error Magnitude for Heat Content}]$$

$$\text{Standard Deviation of Error} = \text{Error estimate}/3$$

$$\text{Variance of Error} = (\text{Standard Deviation of Error})^2$$

Appendix B - Table D-1
 Calculated TRE's and Confidence Intervals
 Non-Halogenated Vents

Table No.	Product	Case A				Case B				Case C			
		TRE Var	TRE	TRE Min Est	TRE Max Est	TRE Var	TRE	TRE Min Est	TRE Max Est	TRE Var	TRE	TRE Min Est	TRE Max Est
2-3	Methyl Methacrylate	0.1111	0.0115	-0.9885	1.0116	0.1111	0.0062	-0.9940	1.0063	0.1113	0.0442	-0.9564	1.0449
2-3	Dimethyl Terephthalate	0.1182	0.0340	-0.9973	1.0653	0.2309	0.0736	-1.3678	1.5151	0.1323	0.1543	-0.9367	1.2454
2-2	Ethylene Oxide	63.6684	0.8424	-23.8953	24.7801	1.9745	0.1471	-4.0684	4.3626	0.1777	0.0635	-1.2010	1.3279
2-2	Acrylonitrile	0.5609	1.2100	-1.0368	3.4568	0.1243	0.2066	-0.8511	1.2643	0.1122	0.1829	-0.8220	1.1878
2-2	Maleic Anhydride	9.0693	1.1729	-7.8617	10.2075	0.3737	0.2039	-1.6302	2.0379	0.1206	0.0751	-0.9667	1.1168
2-5	Air Oxidation	1.0255	1.1590	-1.8791	4.1970	0.1380	0.2048	-0.9096	1.3192	0.2260	0.1075	-1.3188	1.5337
2-5	Distillation V	0.1111	0.0936	-0.9065	1.0936	0.1112	0.0649	-0.9356	1.0654	0.1118	0.2483	-0.7547	1.2513
2-3	Acetic Acid	0.1111	0.1585	-0.8416	1.1586	0.1111	0.0685	-0.9316	1.0687	0.1112	0.3070	-0.6934	1.3075
2-2	Phthalic Anhydride	0.1360	1.8409	0.7344	2.9474	0.1118	0.3177	-0.6856	1.3210	0.1113	0.1059	-0.8949	1.1067
2-3	Butadiene	0.1289	0.0753	-1.0018	1.1523	0.4100	0.1531	-1.7678	2.0740	0.1613	0.1827	-1.0220	1.3875
2-4	Styrene	0.1570	0.5105	-0.6781	1.6991	0.1130	0.1084	-0.9002	1.1170	0.1126	0.2109	-0.7958	1.2176
2-3	Methanol	0.1249	0.0999	-0.9601	1.1600	0.3404	0.1253	-1.6250	1.8757	0.1819	0.6168	-0.6627	1.8964
2-2	Formaldehyde	146.8458	1.3187	-35.0353	37.6727	4.4132	0.2535	-6.0488	6.5558	0.2647	0.1347	-1.4088	1.6781
2-4	Nitrobenzene	0.1164	0.1350	-0.8884	1.1584	0.1876	0.1405	-1.1589	1.4399	0.1240	0.2190	-0.8375	1.2755
2-3	Vinyl Acetate	0.1156	0.1377	-0.8822	1.1576	0.1768	0.1465	-1.1149	1.4079	0.1222	0.2261	-0.8227	1.2748
2-5	Distillation MV	0.1253	0.1623	-0.8998	1.2244	0.3312	0.1855	-1.5410	1.9120	0.1494	0.3345	-0.8252	1.4943
2-3	Cyclohexanone/cyclohexane	0.1111	0.2671	-0.7329	1.2672	0.1111	0.1872	-0.8129	1.1873	0.1113	0.3394	-0.6613	1.3401
2-4	Ethylbenzene	0.1132	0.2779	-0.7313	1.2871	0.1220	0.2263	-0.8214	1.2740	0.1130	0.3773	-0.6311	1.3856
2-5	Dehydrogenation	0.1576	0.6591	-0.5320	1.8503	0.1278	0.2405	-0.8321	1.3130	0.1151	0.3992	-0.6185	1.4169
2-5	Nitration	0.1860	0.8661	-0.4278	2.1600	0.1139	0.3093	-0.7033	1.3220	0.1114	0.3969	-0.6044	1.3981
2-3	Methyl Ethyl Ketone	0.4088	0.3865	-1.5315	2.3046	5.1412	0.9397	-5.8625	7.7420	0.9543	1.0118	-1.9189	3.9425
2-3	Ethyl Acrylate	0.4256	1.1070	-0.8501	3.0642	0.2275	0.4468	-0.9842	1.8777	161.9800	3.2383	-34.9431	41.4197
2-2	Acetaldehyde	40242.8263	9.1749	-592.6435	610.9933	1180.0241	1.6737	-101.3807	104.7281	42.2015	0.5417	-18.9471	20.0305
2-4	Ethylene Glycol Mono	0.1149	0.7795	-0.2375	1.7965	0.1269	0.6281	-0.4405	1.6966	0.1381	1.8334	0.7185	2.9484
2-3	Ethylacetate	0.6123	0.6547	-1.6928	3.0022	8.3623	1.0119	-7.6634	9.6872	1.4933	1.1857	-2.4803	4.8518
2-2	Terephthalic Acid	237324.0196	22.0153	-1439.4621	1483.4927	6957.8079	3.8166	-246.4238	254.0570	248.5687	1.1167	-46.1814	48.4149
2-5	Hydrogenation	0.8615	3.3217	0.5373	6.1062	2.4152	1.1876	-3.4747	5.8498	16.4346	22.0431	9.8813	34.2050

2-4	Benzene	2.0352	6.0695	1.7897	10.3494	0.2307	1.6003	0.1594	3.0412	0.1239	1.2863	0.2302	2.3423
2-5	Catalytic Reforming	2.0352	6.0695	1.7897	10.3494	0.2307	1.6003	0.1594	3.0412	0.1239	1.2863	0.2302	2.3423
2-3	Nitrobenzene	0.1822	1.3593	0.0786	2.6400	1.0725	1.4040	-1.7028	4.5109	0.2721	2.0057	0.4408	3.5706
2-5	Hydrodimerization	1.4576	5.2158	1.5939	8.8378	0.1580	1.3844	0.1921	2.5767	0.1158	1.3933	0.3726	2.4141
2-4	Adiponitrile	1.4576	5.2158	1.5939	8.8378	0.1580	1.3844	0.1921	2.5767	0.1158	1.3933	0.3726	2.4141
2-5	Esterification	0.1779	1.8591	0.5939	3.1244	0.3875	1.4752	-0.3922	3.3426	0.1654	2.6302	1.4102	3.8501
2-5	Alkylation	0.3019	2.2660	0.6177	3.9144	1.1222	1.9340	-1.2440	5.1121	0.2801	3.0731	1.4855	4.6608
2-5	Condensation	0.7827	2.2145	-0.4395	4.8686	11.2618	2.8330	-7.2346	12.9006	2.2374	5.7307	1.2434	10.2181
2-3	Terephthalic Acid	0.1456	2.6419	1.4974	3.7865	0.2788	2.2463	0.6622	3.8304	0.1392	3.5796	2.4603	4.6989
2-5	Generic Reaction	0.4111	5.2083	3.2848	7.1317	0.3603	2.4933	0.6926	4.2940	0.1837	3.9549	2.6692	5.2406
2-3	Aniline	413.4198	3.3393	-57.6589	64.3374	7059.0678	17.5673	-234.4875	269.6221	1182.5952	13.5256	-89.6410	116.6923
2-5	Hydroformylation	4.1512	11.2659	5.1536	17.3782	3.7525	3.8910	-1.9204	9.7024	5.8576	15.1770	7.9162	22.4377
2-3	Ethylbenzene	9.1143	7.4024	-1.6545	16.4594	117.0236	7.4209	-25.0324	39.8741	19.6875	10.6012	-2.7100	23.9124
2-5	Oxidation	171.8551	87.3954	48.0673	126.7234	5.1471	16.6619	9.8557	23.4681	0.3378	7.5892	5.8456	9.3327
2-5	Hydrolysis	3.2528	38.9076	33.4969	44.3183	0.2435	21.9082	20.4278	23.3886	0.1212	33.5555	32.5112	34.5999
2-3	Formaldehyde	0.2754	34.0717	32.4973	35.6460	0.2788	26.3569	24.7730	27.9408	0.1387	44.2333	43.1161	45.3505
2-4	Dinitrotoluene	2511.4244	137.3681	-12.9743	287.7104	73.8531	38.7667	12.9853	64.5480	2.7564	36.7389	31.7582	41.7196
2-5	Sulfonation	12858.3934	278.7263	-61.4583	618.9109	377.1893	62.9701	4.7060	121.2342	13.5723	41.3092	30.2571	52.3614
2-4	Vinyl Acetate	48.9730	49.6944	28.7001	70.6886	697.1383	52.1850	-27.0251	131.3952	116.8428	71.4821	39.0539	103.9102
2-5	Oxyacetylation	48.9730	49.6944	28.7001	70.6886	697.1383	52.1850	-27.0251	131.3952	116.8428	71.4821	39.0539	103.9102

Appendix B - Table D-2
 Calculated TRE's and
 Confidence Intervals
 Halogenated Vents

Table No.	Product	Halogenated			
		TRE Var	TRE	TRE Min Est	TRE Max Est
2-4	Vinylidene Chloride	ERR	0.1282	ERR	ERR
2-5	Dehydrohalogenation	ERR	0.2558	ERR	ERR
2-3	Chlorobenzene	0.1112	0.4214	-0.5791	1.4219
2-4	Chlorobenzene	0.1111	1.5988	0.5988	2.5988
2-5	Oxyhalogenation	0.1142	1.7435	0.7296	2.7574
2-4	Methyl Chloride	0.1140	2.5018	1.4887	3.5149
2-4	Ethylene Dichloride	0.1162	2.2152	1.1924	3.2380
2-3	Perchloroethylene	0.1111	6.2867	5.2867	7.2867
2-5	Halogenation	0.1157	3.9161	2.8956	4.9366
2-5	Hydrohalogenation	0.3497	9.1758	7.4017	10.9499

APPENDIX B - TABLE D

NOTES:

CASE A: Coefficients for TRE Equation from Existing Vent Entries for Non-Halogenated Vents, Flare Basis

CASE B: Coefficients for TRE Equation from Existing Vent Entries for Non-Halogenated Vents, Flare Basis, Thermal Incinerator 0 Per Cent Heat Recovery Basis

CASE C: Coefficients for TRE Equation from Existing Vent Entries for Non-Halogenated Vents, Flare Basis, Thermal Incinerator 70 Per Cent Heat Recovery Basis

CASE D: Coefficients for TRE Equation From Existing Vent Entries for Halogenated Vents, Thermal Incinerator and Scrubber Basis

$TRE(VAR) = [Equation\ From\ Appendix\ A]$

$TRE\ Min\ Est = TRE - 3 \times (TRE\ (VAR))^{1/2}$

$TRE\ Max\ Est = TRE + 3 \times (TRE\ (VAR))^{1/2}$

APPENDIX H

REVCO SCIENTIFIC

276 Aiken Road
Asheville, NC 28804
(704) 658-2711

FAX No. (704) 658-4287
1-800-252-7777 ext.840

To: Ms. Annette Stanley, CMA

April 5, 1993

Subject: Solvent Vapor Recovery Systems by Condensation,
System Design Differences between 85% and 95% Recovery

cc: Mr. John Dege, Issue Manager, DuPont

Dear Ms. Stanley,

I was asked by Mr. John Dege of DuPont to provide you with a formal response from Revco Scientific, Inc. (a solvent vapor recovery system manufacturer) regarding the impact of either upgrading existing equipment, or designing new equipment to achieve recovery percentage at a 95% level versus 85%. To do this effectively, I would like to site the following example.

Suppose an existing recovery system was operating currently in a 77F ambient, and recovering a saturated acetone/air mixture to a level of 85% recovery. Viewing this problem strictly from a vapor pressure reduction basis, the equipment is required to drop the exit vapor condition to roughly +19F to accomplish 85% recovery. Suppose again that the refrigeration load demand was 10,000 Btu/hr. Then, consider a similar recovery system that would reclaim the same exhaust stream of saturated acetone/air but at a 95% recovery level. This system would require dropping the exhaust stream to roughly -11F. A typical refrigeration system that may deliver 10,000 Btu/hr at +19F may only provide 3,500 Btu/hr at -11F. Furthermore, the load required to drop a stream of acetone/air from 77F to -11F versus +19F is nearly 15% greater, mandating a resultant recovery load near 11,500 Btu/hr.

The above example indicates that existing equipment yielding a recovery percentage of 85% could conceivably achieve a lower exhaust temperature to give 95% recovery if and only if the current equipment had roughly a factor of 3 in "over-design" to satisfy the original case for 85% recovery. Most recovery systems designed today have a 25-30% "over-design" factor that would eliminate continuous operation, increase the life of the equipment, and provide the intended recovery percentages when designed peak vapor flow rates are slightly exceeded.

Equipment of this example cited above would require nearly 20% to 30% more energy to operate, not simply the 15% additional capacity stated. Refrigeration systems operate less efficiently when the differential between the inlet and outlet stream temperatures are increased.

I will be happy to provide additional information at your request.

Sincerely,

Mark Kujak
Mark Kujak
Project Engineer

REVCO

APPENDIX I

APPENDIX I

Comparison of EPA and CMA Cost Estimates for Large Storage Tanks

For a 2,000,000 gallon storage tank (100 ft diameter), EPA estimates the cost to install a new floating roof as follows (BID Volume 1 B, p. 3-43):

$$\begin{aligned} \text{Cost } (\$1989) &= 509 * (\text{Tank Diameter, in ft}) + 1160 \\ &= \$52,060 \end{aligned}$$

EPA also estimated the cost to clean a tank prior to installation of a floating roof on an existing tank, i.e., retrofit cost, as follows (BID Volume 1B, p.3-43)

$$\begin{aligned} \text{Cost } (\$1989) &= 7.61 * (\text{Tank Size, in gal})^{0.5132} \\ &= \$13,000 \end{aligned}$$

By comparison, a CMA member company recently arranged for installation of a internal floating roof on a 2,000,000 gallon (100 ft diameter) methanol storage tank. The vendor price quoted for this installation was \$150,507. This price does not include the cost of tank cleaning. See attached letter from Charles E. Branthoover of Petrex Inc. to E.I. duPont de Nemours & Co. dated May 13, 1992. The company reports that actual capital cost for the floating roof installation exceeded the vendor quote by about \$100,000.

Additional information on the cost of retrofitting existing large storage tanks with an floating roofs was supplied by another CMA member company. This company retrofitted two 1,000,000 gallon methylmethacrylate tanks with double seal aluminum floating roofs. The installed cost of the roofs was \$100,000. The cost of cleaning the tanks and disposal of the sludge from the bottom of the tanks was \$1,000,000.

At another facility, an estimate was made for installing a floating roof on a 1,500,000 gallon tank by the end of 1993 (for the Early Reduction Program). The estimated cost was \$389,000 (including \$208,000 for tank cleaning, tank repairs/changes to accommodate roofs, site preparation and mobilization; \$124,000 for the roofs and installation; and \$57,000 for engineering and contingencies.

PETREX Inc.

2349 Dorcon Road • P. O. Box 907 • Warren, Pennsylvania 16365
Telephone 814-723-2050 • Telefax 814-723-2055

November 19, 1992

E.I. DuPont De Nemours & Company
Worthington, Ohio

Att: Carol Collins

PETREX Job No.901-01

The following is additional information required for your P.O. #LAB89337M. Due to design changes and knew information from your Mr. "Z" Andreou, pricing is as follows:

DOCUMENT #A: Amendment to P.O. # LAB89337M

P.O. Amount is NTE.....\$110,000

Balance for Materials.....\$ 2,665

Balance for Installation.....\$37,842

Credits...10) Shell Vents	\$ 529
1) Std. Center Vent	109
1) Gauge Funnel - S/S	80
1) RTG Well/Seal - S/S	121
49) Fixed-Position Legs	5,645

Sub total.....(\$6,485)

Add-Ons.....9) Periphial Vents	\$ 3,675
1) Modified Center Vent	315
1) 8" Ø Gauge Pipe Well/Seal	209
49) Leg Pads S/S	1,653
50) Drains (installed)	3,025
49) 2-Position Legs	13,043
36) Add'L Floatation Panels (Installed) (2' x 8" Panel)	1,983

Sub total..... \$23,903

Total Collective Balance \$57,925

Taxes: State and/or local sales taxes are not included. If applicable, will be added to final invoice unless provided with Exemption Certificates or Direct Payment Number.

031050

SENT BY:

04-05-93 10:28AM

031690→

302 773 4052 # 3

PETREX Inc.

2349 Dorcan Road • P. O. Box 207 • Warren, Pennsylvania 16365
Telephone 814-723-2050 • Telefax 814-723-2035 • Telex 510 101 3005

May 13, 1992
Quotation 2597 Revised

E. I. DuPont De Nemours & Co., (Inc.)
Agricultural Products
901 W. DuPont Ave.
Belle, WV 25015

FAX: 304-357-1230

Attention: Zissis (Z.) Andreou

Gentlemen:

We are pleased to provide a price for our manufacturing, delivering and installing a PETREX Fiberglass Internal Floating Roof System in your 100' @ methanol storage tank at your Belle, West Virginia site.

As a result of the site visit by W. L. Wagner and F. L. Blumquist on March 24, 1992, and careful review of the original bid of July 27, 1990, and subsequent repricing, we find we can hold our price as quoted in our Quotation No. 2597, dated July 27, 1990.

The price quoted was \$ 150,507.

Although panel prices have risen considerably since the budgetary price was proffered, through refined manufacturing techniques and procurement of stainless hardware factory direct we find the trade-off leaves us in a position of being able to hold the budgetary price as quoted.

The following is offered:

Legs will be "fixed" rather than "adjustable" which will allow for zero emissions, since legs terminate under the panel.

Seals will be double wiper type of a special Mesa material which we find is better suited for methanol applications.

Shell overflow vents and roof inspection hatch/vents will be provided. All "hot work" involving vent installation, cutting a roof slot (for crane admission of materials), installing cables, and etc., will be subcontracted. We prefer to go through the roof rather than cutting through the firewall and tank shell (which may require radiographic inspection of rewelded door sheet).
NOTE: There appears to be nothing in API 653 addressing cutting through fire walls or dikes.

Taxes are not included in our proposal; will be added to invoicing if required.

We are aware of DuPont safety requirements and have allowed for manway standby, etc., in our proposal.

Handwritten notes:
3510
5/13/92
3:32
Hypalon
in wiper seals
Need Maxton
3-639-4442
- (C) - A, J, H, W
10/1/92

E.I. DuPont de Nemours & Co. (Inc.)
Page two

May 13, 1992
Quotation 2597 Revised

The following assumptions are made:

Firewall will be drained of water and tank manways removed as needed by DuPont at no cost to PETREX, to facilitate access to tank by installation crew.

Buttoning up will be by DuPont or others at no cost to PETREX.

Terms and conditions are in Attachment A and Sales Terms and Conditions attached. We respectfully request these be included in our contract since they incorporate items specifically related to our product and method of doing work.

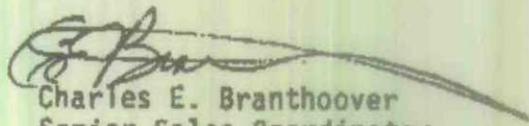
Delivery is dependent upon early receipt of order. If we receive an order or confirmed commitment from DuPont by Friday of this week, May 15, 1992, our vendors assure us we will have materials in time to be on site approximately July 19, 1992. The earliest we can be on site otherwise is mid-August.

We have reserved a field crew for July 19, 1992, depending on your decision. Please advise.

We thank you for the opportunity to quote on your requirement and if successful with an order request this proposal and all attachments be made a part of the contract as an inclusion or by reference.

If you have any questions please call.

PETREX, Inc.


Charles E. Branthoover
Senior Sales Coordinator

CEB/br

Encls.

PETREX Inc.

2349 Dorcon Road • P. O. Box 807 • Warren, Pennsylvania 16365
 Telephone 814-723-2050 • Telefax 814-723-2055 • Telex 510 101 3005

July 27, 1990
 Quotation No. 2597

DuPont
 Building 325
 901 West DuPont Avenue
 Belle, WV 25015

Attention: Bill Sentman

Subject: Internal Floating Roof Pricing for Eleven (11)
 Methanol Storage Tanks at Bell, West Virginia site

Gentlemen:

Per your request for revised pricing for internal floating roofs utilizing fiberglass sandwich panels as an alternate to the steel pans, we offer the following:

Materials, F.O.B. Belle, West Virginia and installed

<u>22' Ø</u>	<u>48' Ø</u>	<u>100' Ø</u>
\$ 13,739 each x 4 tanks	\$ 40,853 each x 6 tanks	\$ 150,507 1 tank
<u>\$ 54,956</u>	<u>\$ 245,118</u>	<u>\$ 150,507</u>

Total 11 tanks \$ 450,581

Assume an additional \$ 858 for each move-in/move-out .

Each internal floating roof utilizes fiberglass sandwich panels with stainless steel hardware (304 stainless), including stainless steel legs.

Perimeter seal is liquid mounted foam log type with polyurethane wrap.

Vents for the tank shell, as required per API 650, and one center vent, are included for each tank.

Hot work to install vents, cables, and cut and reweld a roof slot, is also included in pricing.

A rental crane is needed and will be charged at cost plus 15%. This has not been included in the above pricing since DuPont has a crane on site that may be available at no cost to PETREX (per Bill Sentman).

As noted in the pricing above, we have indicated a separate charge for the move-in/move-out of our installation crew. In conversation with Mr. Bill

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Page two

July 27, 1990
Quotation No. 2597

Sentman, we understand the eleven tanks will be made available in sequence and anticipate our installation crew remaining on site throughout the installation schedule.

No provision has been made for down time should there be a delay between tanks and this will have to be arranged either with additional moves at the applicable rate or negotiated at an applicable hourly rate.

We anticipate delivering all materials at one time and will store them at site until needed. It is our understanding that this is not a problem.

Other terms and conditions are as in Attachment A, copy enclosed.

Taxes are not included in the above pricing and will be added to invoicing as applicable.

Should we be honored with a contract, provision for progressive billing will be required for materials, manufacture, and installation.

Please be advised if you need additional information.

Thank you for the opportunity to quote on your requirements.

Very truly yours,

PETREX, Inc.

C. E. Branthoover
Estimator

CEB/br

cc: Emil Pawuk and Associates, Inc.

PETREX

APPENDIX J



APPENDIX J

ENSR Consulting
and Engineering
35 Nagog Park
Acton, Massachusetts 01720
(508) 635-9500
(508) 635-9180 (FAX)

March 17, 1993

ENSR Ref. No: 1410-013-200
ENSR Doc. No: 019EPD03.ADS

Ms. Annette Stanley
Chemical Manufacturers Association
2501 M Street, N.W.
Washington, DC 20037

Re: CMA Contract No. 608-71-018, Task 2A - Comparison of HON Storage Tank Equations with AP-42 Supplement E

Dear Annette:

ENSR has evaluated Subpart G of the Proposed HON for consistency with EPA's most recent supplement to the Compilation of Air Pollutant Emission Factors (AP-42). Supplement E (dated October 1992) contains a new chapter, Chapter 12, entitled "Storage of Organic Liquids". EPA intends for this chapter to replace the old Section 4.3 of AP-42 with the same title, which was last updated in September 1985.

The HON does not reflect new material contained in Supplement E, based on our review. Supplement E makes few changes to the calculations recommended in Section 4.3 of AP-42, but the changes that have been made are not included in the HON. Our review is summarized below.

The HON contains a series of twelve equations for estimating HAP air emissions from storage tanks. Each of these equations (or an equivalent version) appeared first in Section 4.3 of AP-42. These equations and their purposes are listed in Table 1. We identified these equations in our April 1992 report to CMA, "Compilation and Review of Equations in the Hazardous Organic NESHAP, Subpart G" (ENSR Report No. 1410-011-002). Table 1 shows the equation numbers from April 1992 report as well as the applicable page number in the Proposed HON, for easy cross-referencing. Table 1 also indicates which equations should be updated to reflect Supplement E.

Supplement E differs from the HON in the following three equations:



March 18, 1993
 Ms. Annette Stanley
 Page 2

1. Fixed Roof Tank - Breathing Losses

The most important change in Supplement E vs Section 4.3 is the calculation of breathing losses from fixed roof storage tanks. This corresponds with Equation 39 of our April 1992 report, found on page 739 of the Proposed HON. The new equation in Supplement E is:

$$L_s = 365 V_v W_v K_E K_S$$

where:

L_s = standing storage loss, lb/yr

V_v = vapor space volume, ft³

W_v = vapor density, lb/ft³

K_E = vapor space expansion factor, dimensionless

K_S = vented vapor saturation factor, dimensionless

365 = constant, days/year

Supplement E also provides a series of 21 other equations which are used to calculate the values of V_v , W_v , K_E and K_S . The relevant pages (pp. 12-21 to 12-30) of Supplement E are attached.

The form of the new equation differs completely from the old one. Determination of the conditions under which the two equations are equivalent, if any, and the differences in their results is beyond the scope of this task. We presume that the new equation in Supplement E was published in a recent API document, but this could not be readily verified.

2. Fixed Roof Tank - Working Losses

The equation for calculating working losses from fixed roof tanks in Supplement E differs from the one in Section 4.3 (which is the basis for the equation in the HON). However, they are computationally equivalent; i.e. they yield the same result. One of the terms of the equation has been slightly redefined in the Supplement E equation. The liquid vapor

ENSR

March 17, 1993
Ms. Annette Stanley
Page 3

equation has been slightly redefined in the Supplement E equation. The liquid vapor pressure, P, is defined at the liquid surface temperature in Supplement E, whereas P was defined at the bulk liquid temperature in Section 4.3. Supplement E contains an equation which allows one to calculate the liquid surface temperature based on knowledge of the bulk liquid temperature and the ambient temperature.

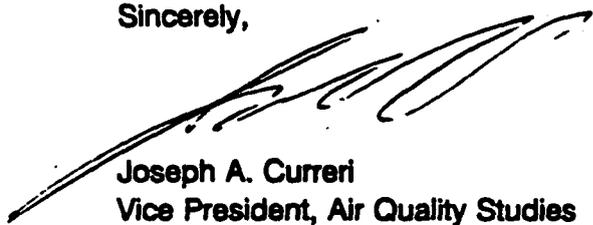
3. Internal Floating Roof Vessel - Rim Seal Losses

Supplement E contains a simpler expression for rim seal losses from internal floating roof vessels than Section 4.3. The two equations are equivalent. The new equation appropriately deletes the wind speed terms from the equation, since rim seal emissions from internal floating roof vessels are not influenced by wind speed. There is a table of "rim seal factors" which provides inputs for the equation; this table is included in the HON. One of the entries has been changed in Supplement E. The HON table should be updated to reflect this change.

There is no change in the other nine HON storage tank equations, based on Supplement E. We recommend that EPA be notified of the discrepancies between the HON and AP-42 Supplement E, and that the HON be updated accordingly.

This concludes our Task 2A report. Please do not hesitate to call me or Art Schatz with any questions.

Sincerely,



Joseph A. Curreri
Vice President, Air Quality Studies

cc: Art Schatz

TABLE 1

HON Storage Tank Equations Derived from AP-42

Proposed HON Page No.	ENSR 4/92 ¹ Equation No.	Equation Description	Different from Supplement E
739	38	Total emissions from fixed roof storage tanks (FRST)	No
739	39	Breathing losses from FRST	Yes
740	40	Working losses from FRST	Yes
744	42	Total emissions from internal floating roof vessel (IFRV)	No
744	43	Withdrawal loss for IFRV	No
745	44	Rim seal loss for IFRV	Yes
749	45	Fitting loss for IFRV	No
751	46	Deck seam loss for IFRV	No
754	47	Total emissions from external floating roof vessel (EFRV)	No
756	48	Withdrawal loss for EFRV	No
756	49	Seal loss for EFRV	No
758	50	Fitting loss for EFRV	No

¹Completion and Review of Equations in the Hazardous Organic NESHAP, Subpart G. ENSR report to CMA (4/92), based on 12/91 draft HON.

12.3 EMISSION ESTIMATION PROCEDURES

The following section presents the emission estimation procedures for fixed roof, external floating roof, and internal floating roof tanks. These procedures are valid for all petroleum liquids, pure volatile organic liquids, and chemical mixtures with similar true vapor pressures. It is important to note that in all the emission estimation procedures the physical properties of the vapor do not include the noncondensibles (e.g., air) in the gas but only refer to the condensible components of the stored liquid. To aid in the emission estimation procedures, a list of variables with their corresponding definitions was developed and is presented in Table 12.3-1.

The factors presented in AP-42 are those that are currently available and have been reviewed and approved by the U. S. Environmental Protection Agency. As storage tank equipment vendors design new floating decks and equipment, new emission factors may be developed based on that equipment. If the new emission factors are reviewed and approved, the emission factors will be added to AP-42 during the next update.

The emission estimation procedures outlined in this chapter have been used as the basis for the development of a software program to estimate emissions from storage tanks. The software program entitled "TANKS" is available through the Bulletin Board System maintained by the U. S. Environmental Protection Agency.

12.3.1 Total Losses From Fixed Roof Tanks^{4,6-12}

The following equations, provided to estimate standing storage and working loss emissions, apply to tanks with vertical cylindrical shells and fixed roofs. These tanks must be substantially liquid- and vapor-tight and must operate approximately at atmospheric pressure. Total losses from fixed roof tanks are equal to the sum of the standing storage loss and working loss:

$$L_T = L_S + L_W \tag{1-1}$$

where:

L_T = total losses, lb/yr

L_S = standing storage losses, lb/yr

L_W = working losses, lb/yr

H_L = liquid height, ft

H_{RO} = roof outage, ft; see Note 2 for a cone roof or Note 3 for a dome roof

Notes:

1. The emission estimating equations presented above were developed for vertical fixed roof tanks. If a user needs to estimate emissions from a horizontal fixed roof tank, some of the tank parameters can be modified before using the vertical tank emission estimating equations. First, by assuming that the tank is one-half filled, the surface area of the liquid in the tank is approximately equal to the length of the tank times the diameter of the tank. Next, assume that this area represents a circle, i.e., that the liquid is an upright cylinder. Therefore, the effective diameter, D_E , is then equal to:

$$D_E = \sqrt{\frac{LD}{0.785}} \quad (1-5)$$

where:

D_E = effective tank diameter, ft

L = length of tank, ft

D = actual diameter of tank, ft

One-half of the actual diameter of the horizontal tank should be used as the vapor space outage, H_{VO} . This method yields only a very approximate value for emissions from horizontal storage tanks. For underground horizontal tanks, assume that no breathing or standing storage losses occur ($L_S = 0$) because the insulating nature of the earth limits the diurnal temperature change. No modifications to the working loss equation are necessary for either above-ground or underground horizontal tanks.

2. For a cone roof, the roof outage, H_{RO} , is calculated as follows:

$$H_{RO} = 1/3 H_R \quad (1-6)$$

where:

H_{RO} = roof outage (or shell height equivalent to the volume contained under the roof), ft

H_R = tank roof height, ft

Vapor Density, W_v - The density of vapor is calculated using the following equation:

$$W_v = \frac{M_v P_{VA}}{RT_{LA}} \quad (1-9)$$

where:

W_v = vapor density, lb/ft³

M_v = vapor molecular weight, lb/lb-mole; see Note 1

R = the ideal gas constant, 10.731 psia·ft³/lb-mole·°R

P_{VA} = vapor pressure at daily average liquid surface temperature, psia; see Notes 1 and 2

T_{LA} = daily average liquid surface temperature, °R; see Note 3

Notes:

1. The molecular weight of the vapor, M_v , can be determined from Table 12.3-2 and Table 12.3-3 for selected petroleum liquids and volatile organic liquids, respectively, or by analyzing vapor samples. Where mixtures of organic liquids are stored in a tank, M_v can be calculated from the liquid composition. The molecular weight of the vapor, M_v , is equal to the sum of the molecular weight, M_i , multiplied by the vapor mole fraction, y_i , for each component. The vapor mole fraction is equal to the partial pressure of component i divided by the total vapor pressure. The partial pressure of component i is equal to the true vapor pressure of component i (P) multiplied by the liquid mole fraction, (x_i). Therefore,

$$M_v = \sum M_i y_i = \sum M_i \left(\frac{P x_i}{P_{VA}} \right) \quad (1-10)$$

where: P_{VA} , total vapor pressure of the stored liquid, by Raoult's law, is:

$$P_{VA} = \sum P x_i \quad (1-11)$$

For more detailed information, please refer to Section 12.4.

2. True vapor pressure is the equilibrium partial pressure exerted by a volatile organic liquid, as defined by ASTM-D 2879 or as obtained from standard reference texts. Reid vapor pressure is the absolute vapor pressure of volatile crude oil and volatile nonviscous petroleum liquids, except liquified petroleum gases, as determined by ASTM-D-323. True vapor pressures for organic liquids can be determined from Table 12.3-3. True vapor pressure can be determined for crude oils using Figures 12.3-1A and 12.3-1B. For refined

For organic liquids, the values for the constants A, B, and C are listed in Table 12.3-5. Note that in equation 1-12b, T_{LA} is determined in degrees Celsius instead of degrees Rankine. Also, in equation 1-12b, P_{VA} is determined in mm of Hg rather than psia (760 mm Hg = 14.696 psia).

3. If the daily average liquid surface temperature, T_{LA} , is unknown, it is calculated using the following equation:

$$T_{LA} = 0.44T_{AA} + 0.56T_B + 0.0079 \alpha I \quad (1-13)$$

where:

T_{LA} = daily average liquid surface temperature, °R

T_{AA} = daily average ambient temperature, °R; see Note 4

T_B = liquid bulk temperature, °R; see Note 5

α = tank paint solar absorptance, dimensionless; see Table 12.3-7

I = daily total solar insolation factor, Btu/ft²·day; see Table 12.3-6

If T_{LA} is used to calculate P_{VA} from Figures 12.3.1A through 12.3.2B, T_{LA} must be converted from degrees Rankine to degrees Fahrenheit ($^{\circ}\text{F} = ^{\circ}\text{R} - 460$). If T_{LA} is used to calculate P_{VA} from Equation 1-12b, T_{LA} must be converted from degrees Rankine to degrees Celsius ($^{\circ}\text{C} = (^{\circ}\text{R} - 492)/1.8$). Equation 1-13 should not be used to estimate emissions from insulated tanks. In the case of insulated tanks, the average liquid surface temperature should be based on liquid surface temperature measurements from the tank.

4. The daily average ambient temperature, T_{AA} , is calculated using the following equation:

$$T_{AA} = (T_{AX} + T_{AN})/2 \quad (1-14)$$

where:

T_{AA} = daily average ambient temperature, °R

T_{AX} = daily maximum ambient temperature, °R

T_{AN} = daily minimum ambient temperature, °R

Table 12.3-6 gives values of T_{AX} and T_{AN} for select U.S. cities.

α = tank paint solar absorptance, dimensionless; see Table 12.3-7

I = daily total solar insolation factor, Btu/ft²·day; see Table 12.3-6

2. The daily vapor pressure range, ΔP_V , can be calculated using the following equation:

$$\Delta P_V = P_{VX} - P_{VN} \quad (1-18)$$

where:

ΔP_V = daily vapor pressure range, psia

P_{VX} = vapor pressure at the daily maximum liquid surface temperature, psia; see Note 5

P_{VN} = vapor pressure at the daily minimum liquid surface temperature, psia; see Note 5

The following method can be used as an alternate means of calculating ΔP_V for petroleum liquids:

$$\Delta P_V = \frac{0.50 B P_{VA} \Delta T_V}{T_{LA}^2} \quad (1-19)$$

where:

ΔP_V = daily vapor pressure range, psia

B = constant in the vapor pressure equation, °R; see Note 2 to Equation 1-9

P_{VA} = vapor pressure at the daily average liquid surface temperature, psia; see Notes 1 and 2 to Equation 1-9

T_{LA} = daily average liquid surface temperature, °R; see Note 3 to Equation 1-9

ΔT_V = daily vapor temperature range, °R; see Note 1

3. The breather vent pressure setting range, ΔP_B , is calculated using the following equation:

$$\Delta P_B = P_{BP} - P_{BV} \quad (1-20)$$

where:

ΔP_B = breather vent pressure setting range, psig

APPENDIX K

PROGRESS REPORT**MODELING OF TRAY-TYPE STEAM STRIPPING COLUMNS****to****CHEMICAL MANUFACTURERS ASSOCIATION****by****James R. Fair****Roger Harvey****Separations Research Program
The University of Texas at Austin
Austin, Texas 78712****April 15, 1993**

Introduction

The steam stripping of organics from water is practiced extensively as a means for purifying process waste waters as well as for recovering the organics for possible re-use. The process flow diagram for such an operation is relatively simple (Figure 1): the waste water stream is preheated by exchange with the stripper bottoms stream, the preheated stream is fed to the top of a vertical contacting column, and the countercurrent flow of steam serves to remove the dissolved organics and carry them overhead from the column. The overhead stream is condensed and the resulting liquid is processed further, depending on local conditions and needs. Commonly, the organics separate into an immiscible "oil layer" and the remaining condensate, water with dissolved organics, is recirculated to the column. Thus, the net feed of organics to the column is removed as an immiscible layer (with dissolved water) together with that portion leaving with the bottoms from the column (i.e., the fraction of organics that are not stripped).

The design of the stripper has normally been carried out semi-empirically. Determination of the required theoretical stages has been done graphically, using a McCabe-Thiele type approach, or analytically, using some form of the well-known Kremser equation. This determination is straightforward, as long as the Henry's law coefficient is known for each organic species dissolved in the feed water. Completion of the design to specify the number of actual stages to be installed is not straightforward, however. It requires a knowledge of the mass transfer characteristics of the particular contacting device selected. There are not available reliable methods for converting from theoretical stages to actual stages, for either tray-type or packed-type steam strippers. This general situation has been described recently in a two-part paper by Huang et al. (1992a, 1992b)

The purpose of the present project is to develop a mechanistic model for the prediction of overall column efficiency of sieve-tray type steam stripping columns. This efficiency is defined simply as

$$E_{oc} = \frac{\text{theoretical stages}}{\text{actual stages}} \quad (1)$$

Model Validation

Any predictive model for the design of a piece of chemical processing equipment requires validation against reliable experimental data, at as large a scale as possible. Such validation may only be possible through the *a posteriori* comparison of prediction and result, and this procedure has been

followed countless times in the past. A design method is set forth, some logical value of safety factor is added, and the equipment designed. Then, after the equipment is placed in operation, some comparison is made between design and performance. At times this comparison is quite approximate, especially if the duty of the equipment is being met satisfactorily. It is safe to say that in the past this approach has been used for steam strippers, with an added ingredient of "experience," after several such units have been designed.

Fortunately, for the present work, large-scale experimental data have become available for a sieve-tray steam stripping column. The data have been made available on a restricted basis to the CMA, and they form the framework of the results reported here. The source of the data is Fractionation Research, Inc. (FRI), a private research firm supported by a number of chemical, petroleum, equipment, and engineering contracting firms. The FRI data are of the highest quality, and the experimental basis for them will be described in the final report on the project. For the present, it can be stated that the data were taken on the stripping of toluene from water at very low concentrations, and that the equipment involved was a four-foot diameter column containing crossflow sieve trays at 27-inch spacing. Some basic information on the trays is given in Table 1.

Method of Analysis

Because of the short time available for this work, it was clear that every effort should be made to utilize an existing model for the hydraulics and mass transfer relationships for sieve tray contactors. The most readily-available model was known to be that of the Separations Research Program (SRP) at The University of Texas at Austin. This model had been programmed and made available to SRP sponsors as RATE and could be used for either tray columns or packed columns. The methodology has been described in general by one of the authors (Fair, 1987) and was developed originally for distillation columns. It provides the designer with the expected performance in the pertinent areas of capacity, pressure drop and efficiency. It will be described in detail in the final report on the present project.

As mentioned, the RATE model is based on distillation column operation wherein counterflow diffusion occurs (i.e., components transfer in both directions between liquid and vapor phases. It has been found to represent well the performance of distillation columns handling a variety of mixtures. However, for all such mixtures the controlling mass transfer resistance is in the vapor phase, and thus the correlations for the liquid phase have not been given a fair test. For steam stripping, mass transfer is uni-directional and the liquid phase resistance is very high compared with the vapor phase resistance. Thus, for the present project it was expected that some adjustment in the liquid phase mass transfer relationships would be needed. And this indeed turned out to be the case.

Efficiency Results

The FRI data embrace a combination of liquid and gas flow rates, with all tests being performed on a single sieve tray design. The tests were run at atmospheric pressure, with the column temperatures being close to the boiling temperature of water. Steam for stripping was generated in the column reboiler by vaporizing a portion of the column bottoms stream. The solute was toluene, typically at initial concentrations in the range of 200-300 parts per million by weight. Equilibrium data for toluene-water were analyzed carefully by Hooper and Prausnitz (1988). Intermediate tray liquid samples were taken by FRI and analyzed, to provide support for the equilibrium stage determinations.

Comparisons between the measured and predicted efficiency values are shown in Figures 2-5. The agreement appears to be reasonable, considering the scatter of the original data and the need to apply readily-available methodology.

Hydraulics Results

Comparisons between measured and calculated pressure drop values are shown in Figures 6-9. Agreement is reasonable except for the high liquid flow case. No adjustments in the published model have been made.

Only two flooding runs were reported by FRI, and these have not yet been analyzed. One would expect that the existing models (Fair, 1987) would be adequate for design purposes, since they have been shown to be generally conservative (AIChE, 1990).

Summary and Conclusions

The FRI steam stripping experimental data have been compared with data generated through the use of publicly-available models for the prediction of crossflow sieve tray performance. The comparison is reasonably good, and requires only one adjustment in a model that heretofore has been validated only against distillation data. While the FRI tests cover only one solute (toluene) and one sieve tray design, it appears that the model can be used with confidence for designs of other systems and tray geometries. This is because the model is mechanistically-based and takes into account flow rates and physical properties of the contacting phases as well as the geometric variables of the tray.

Future Plans

A parametric study of tray design variables will be carried out, using toluene as the solute to be stripped. These variables will include weir height, hole diameter and hole open area, as well as operating pressure.

A series of designs will be prepared for a variety of solutes, chosen for their volatility and their solubility in water.

A final report will be prepared which will include complete descriptions of the models used and the availability of the computer programs that were used in the analysis.

Recommendations

Two recommendations are apparent. More data are needed for a complete validation of the tray design model, using other solutes and other tray geometries. And data should be sought for the design of packed-type steam stripping columns; this may require contracting for the acquisition of data at larger column diameters.

Table 1. Dimensions of FRI Test Trays

Column diameter, in.	48
Tray spacing, in.	27
Outlet weir height, in.	2.0
Hole diameter, in.	0.25
Downcomer baffle clearance, in.	1.50
Column cross sectional area, ft ²	12.57
Downcomer area*, ft ²	1.50
Active area, ft ²	9.57
Hole area, ft ²	0.693

*Straight downcomers, segmental cross section.

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Fair, J. R., "Distillation," Chapter 5 in *Handbook of Separation Processes*, R. W. Rousseau, editor. New York, John Wiley, 1987.

Hooper, H., Prausnitz, J.M., *Vapor-Liquid Equilibria for Toluene in Water and for Water in N-Heptane or Cyclohexane in the Region 70-250° F.* Topical Report No. 105, Fractionation Research, Inc., Stillwater, Oklahoma, June 1988.

Huang, Y-L, Keller, G. E., Olson, J. D., "Steam Stripping for Removal of Organic Pollutants from Water. 1. Stripping Effectiveness and Stripper Design." *Ind. Eng. Chem. Research* 31, 1753 (1992a).

Huang, Y-L, Olson, J. D., Keller, G. E., "Steam Stripping for Removal of Organic Pollutants from Water. 2. Vapor-Liquid Equilibrium Data." *Ind. Eng. Chem. Research* 31, 1759 (1992b).

Sakata, M., Ognisty, T. P., Santoso, E., Kunesh, J. G., "Progress Report - July-August 1988", Fractionation Research, Inc., Stillwater, Oklahoma, 1988. [Test data for steam stripping of toluene from water.]

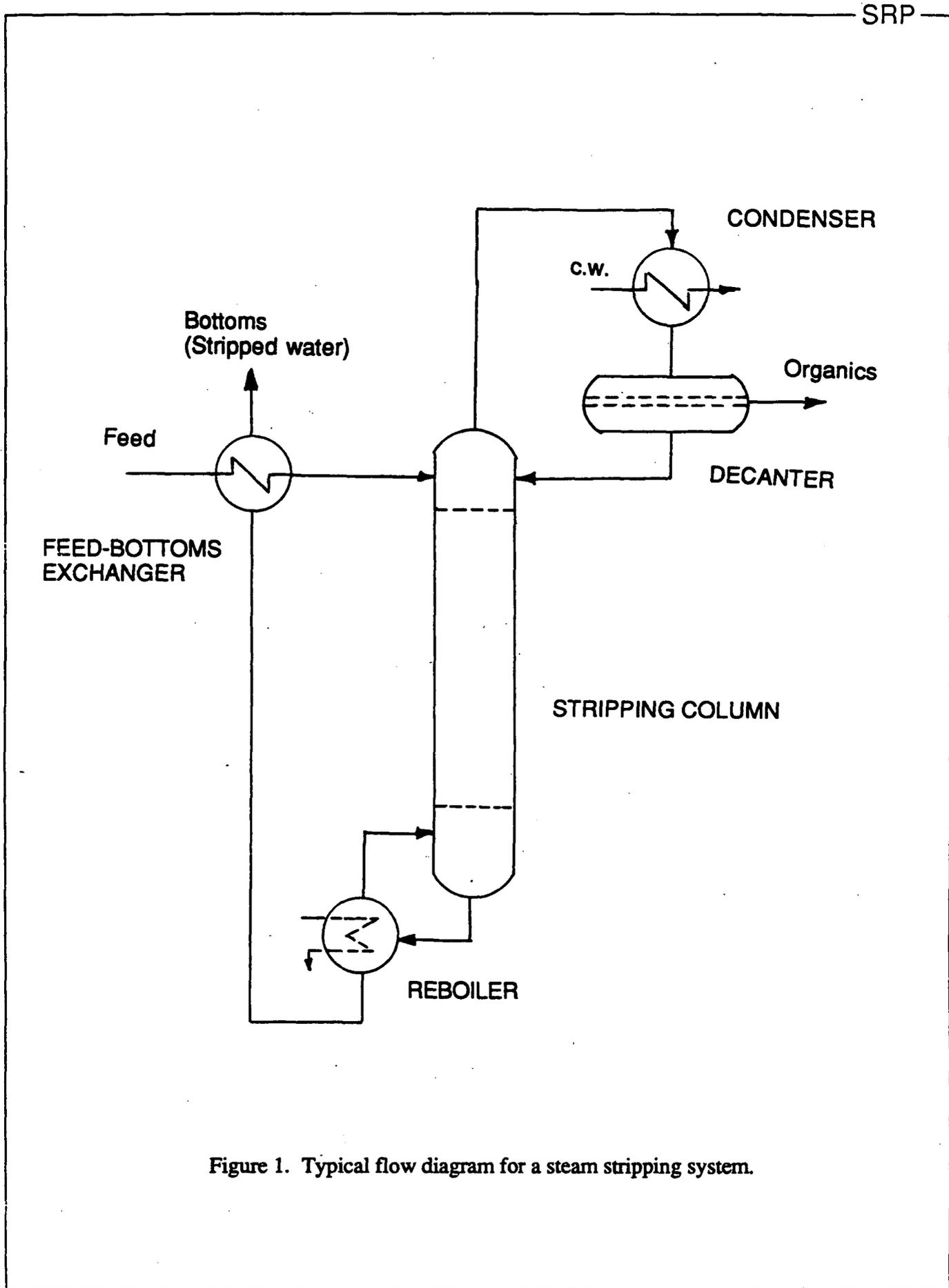


Figure 1. Typical flow diagram for a steam stripping system.

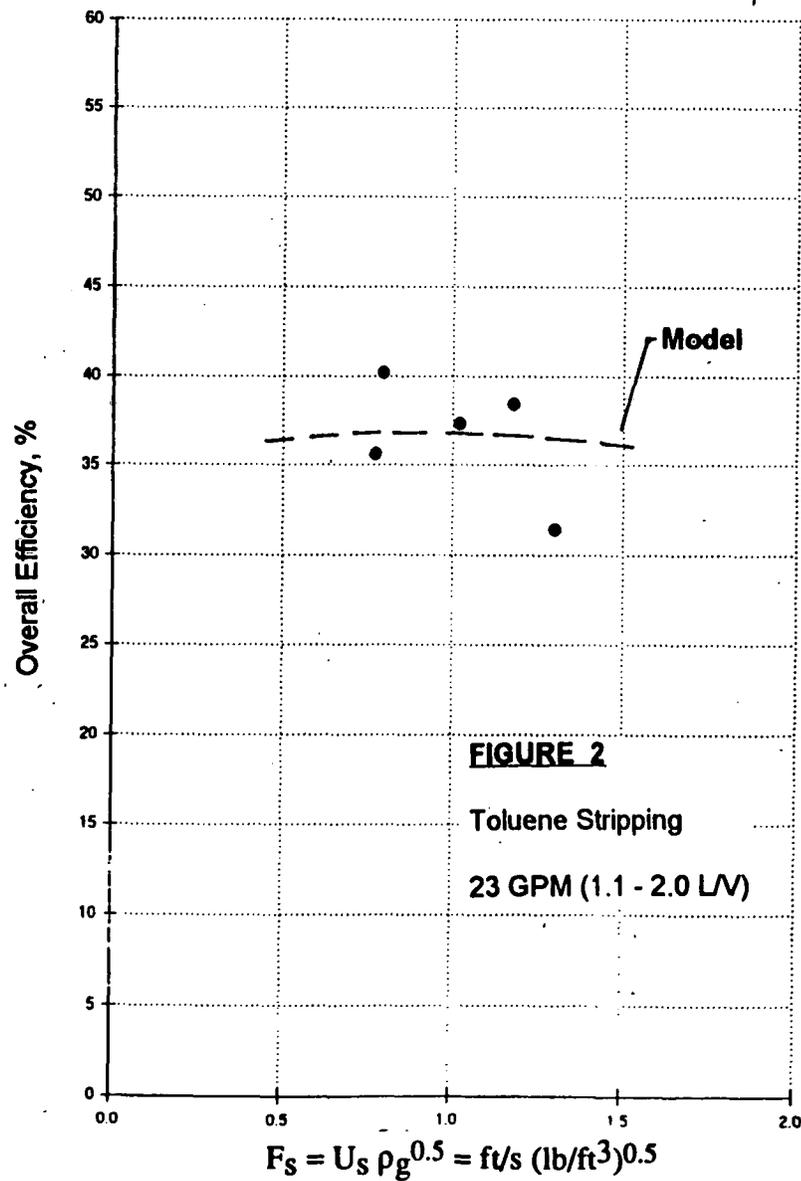


Figure 2. Overall efficiency for an average liquid rate of 23 gal/min (0.62 gal/min/in. weir)

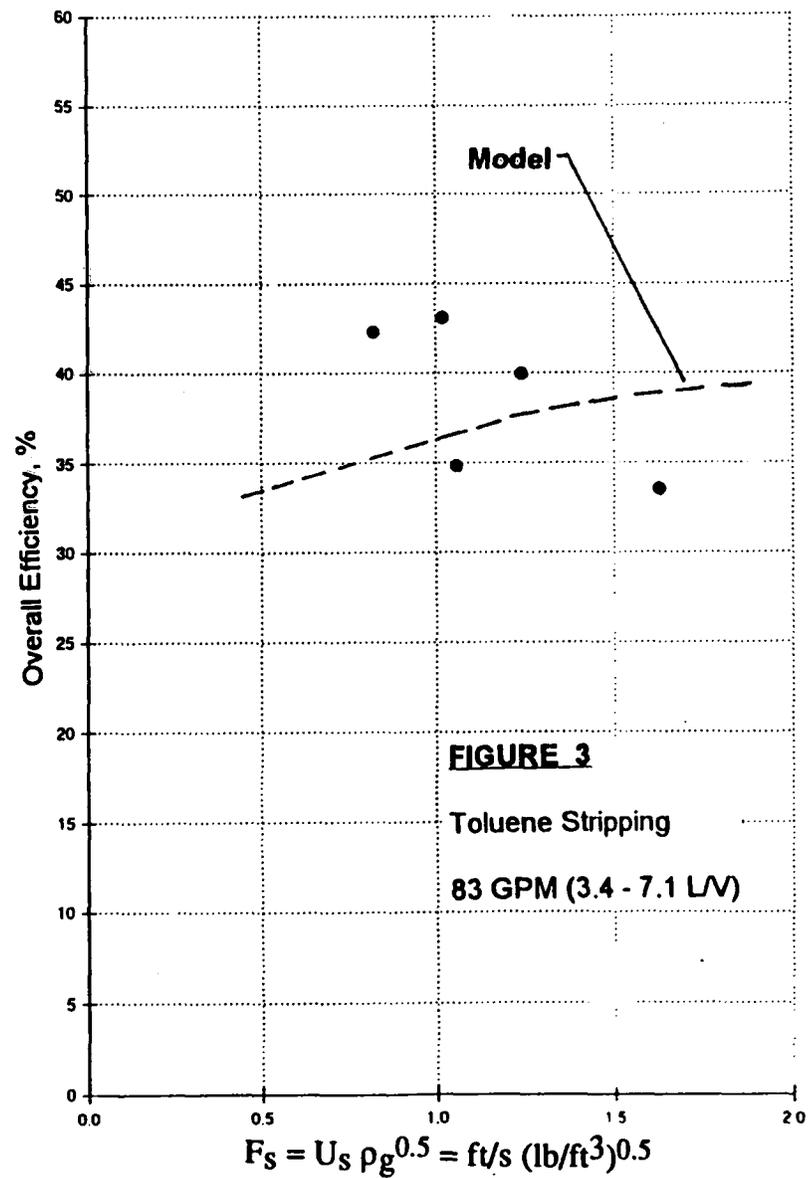


Figure 3. Overall efficiency for an average liquid rate of 83 gal/min (2.24 gal/min/in. weir).

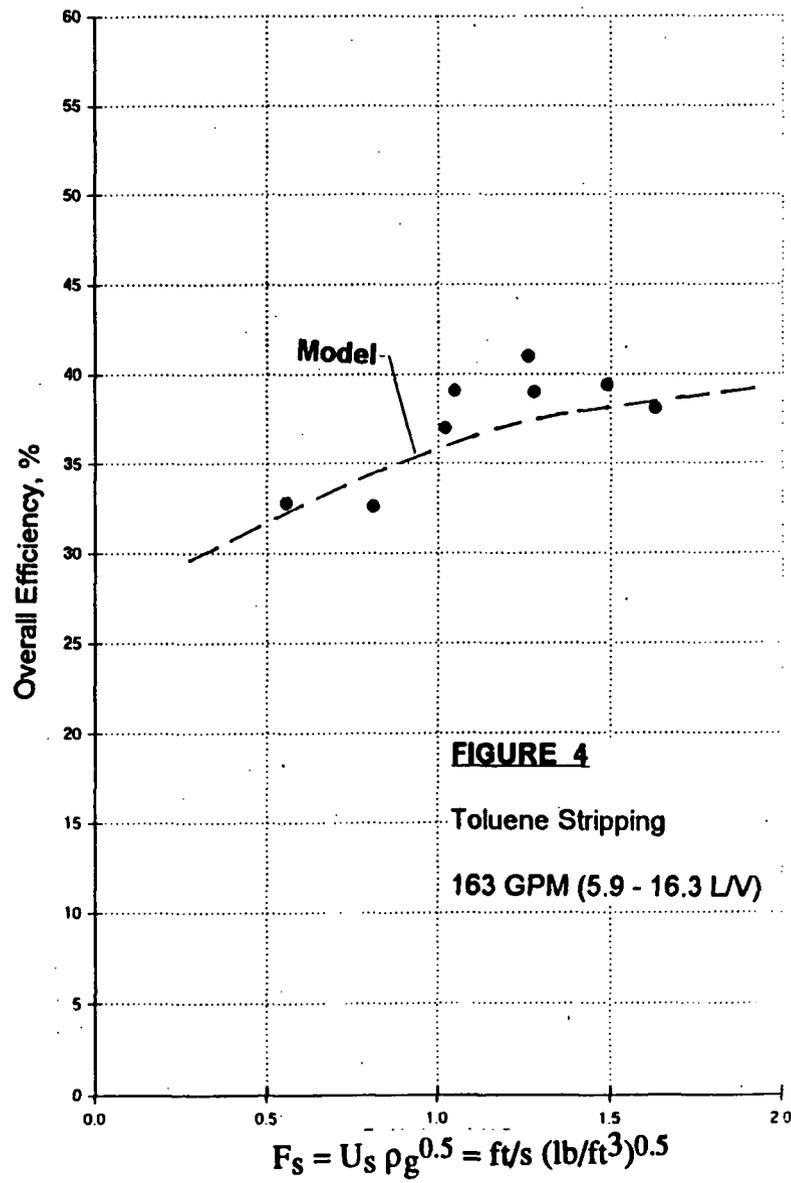


Figure 4. Overall efficiency for an average liquid rate of 163 gal/min (4.40 gal/min/in. weir).

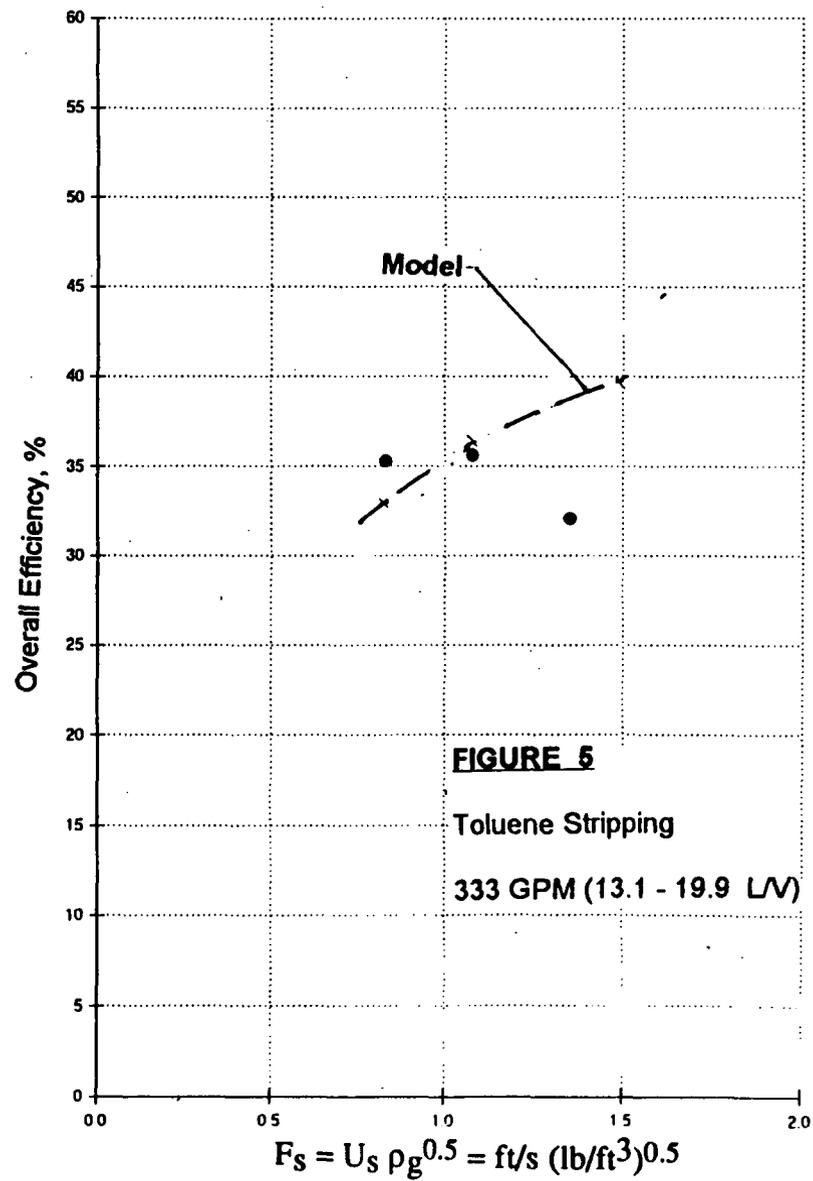


Figure 5. Overall efficiency for an average liquid rate of 333 gal/min (9.00 gal/min/in. weir).

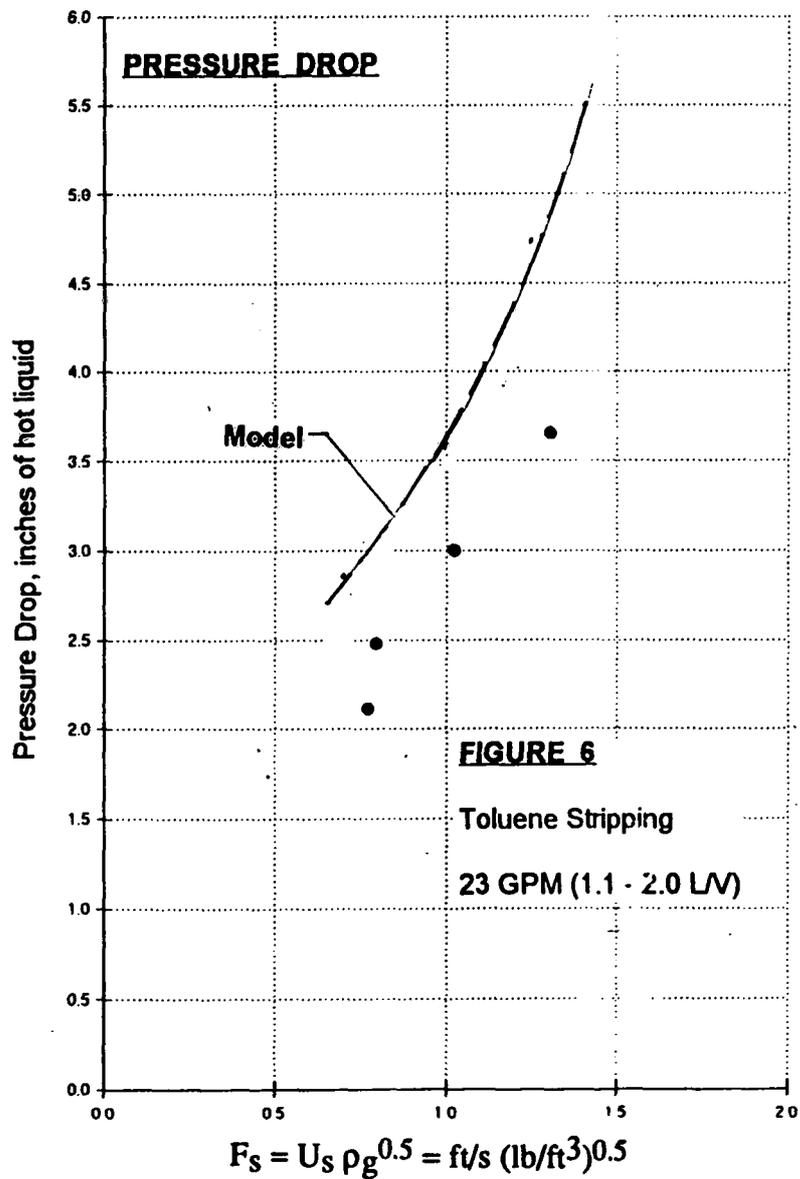


Figure 6. Tray pressure drop for an average liquid rate of 23 gal/min (0.62 gal/min/in. weir).

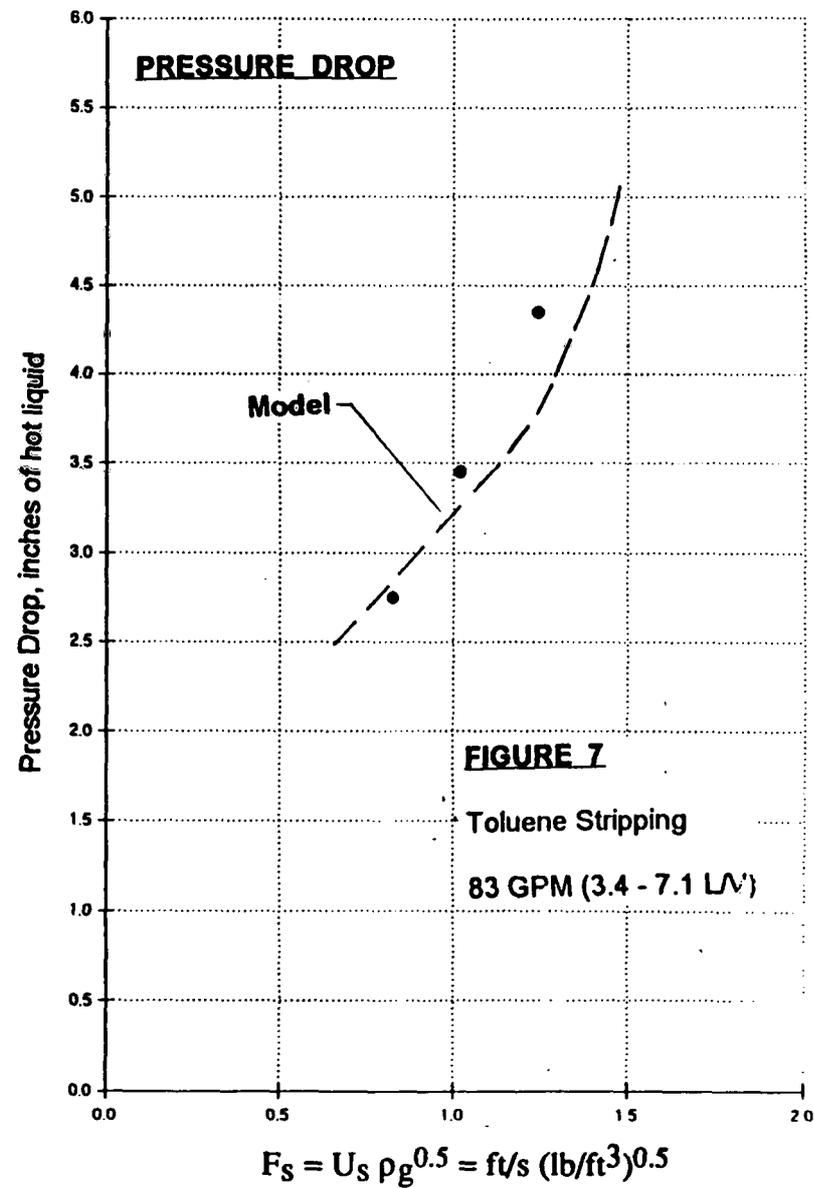


Figure 7. Tray pressure drop for an average liquid rate of 83 gal/min (2.24 gal/min/in. weir).

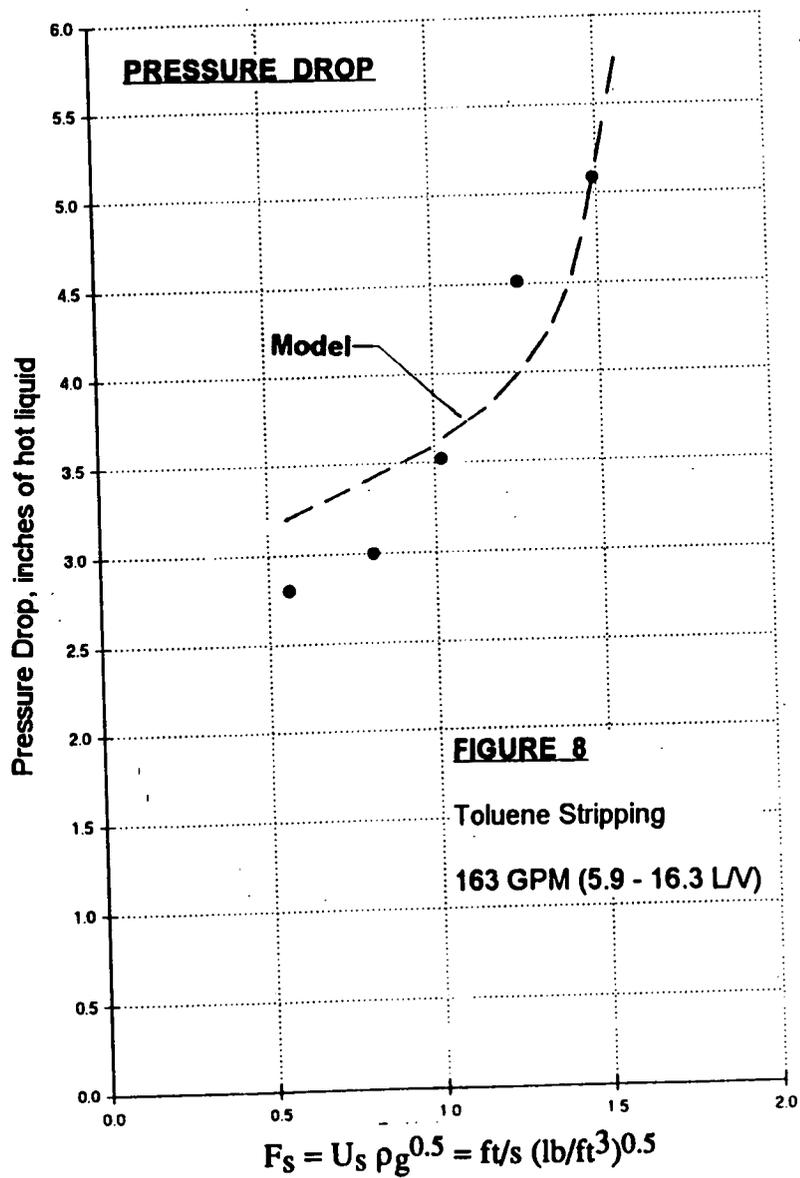


Figure 8. Tray pressure drop for an average liquid rate of 163 gal/min (4.40 gal/min/in. weir).

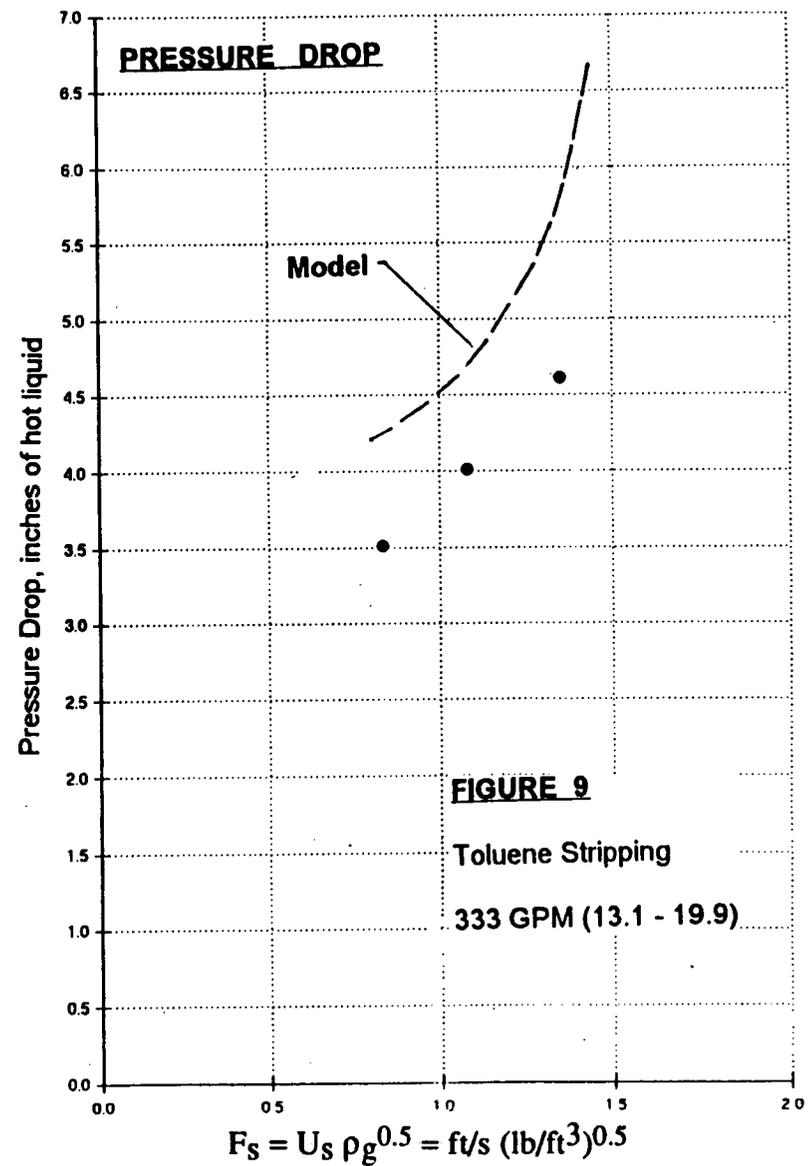


Figure 9. Tray pressure drop for an average liquid rate of 333 gal/min (9.00 gal/min/in. weir).

APPENDIX A
FRACTIONATION RESEARCH, INC.
DATA

PROGRESS REPORT
July-August 1988

by

M. Sakata
T. P. Ognisty
E. Santoso
J. G. Kunesh

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TABLE I (English Units)
FRI Distillation Unit Experimental Data
4 Foot Diameter High Pressure Column
13% Straight Downcomer, 27 inches Tray Spacing
7.5% Sieve Tray, 1/2 inches Holes on 1.5 inches Triangular Spacing
2 inches by 37 inches Outlet Weir, 1.5 inches Downcomer Clearance
Trace Toluene In Water, Atmospheric Pressure

Run Number	16533	16534	16535	16536	16537	16538	16543	16544	16545	16546	16547
Run Type	L/V										
L/V	10.3	8.24	5.19	4.31	1.17	8.37	7.09	13.7	6.66	3.36	2.04
Reboiler Duty, MM BTU/hr	7.33	9.14	7.33	9.00	8.48	9.01	5.85	5.79	11.9	12.2	5.52
Condenser Duty, MM BTU/hr	7.49	9.29	7.21	9.05	8.47	8.88	5.80	5.73	11.9	11.9	5.39
Overhead Product Rate, M lbs/hr	7.39	8.93	7.62	8.71	8.08	8.85	5.78	5.89	11.1	12.0	5.11
Bottoms Rate, M lbs/hr	68.5	67.9	30.7	30.1	2.65	64.5	34.7	74.4	68.8	34.0	5.62
Feed Rate, M lbs/hr	77.1	77.0	38.8	39.0	9.53	76.9	41.8	80.0	80.2	40.8	10.9
Feed Location	TOP										
Tower Top Pressure, psia	15.4	15.8	15.3	15.6	15.4	15.5	14.8	14.8	16.1	16.1	14.9
Pressure Drop, inches of Hot Liquid											
Trays 1-6	-	-	-	-	-	-	16.5	17.9	27.5	26.3	13.0
Trays 1-3	-	-	-	-	-	-	8.21	8.95	13.8	13.1	6.45
Trays 4-6	-	-	-	-	-	-	8.37	8.85	13.7	13.2	6.59
Tray 3 Bubblers, inches of Hot Liquid											
Inlet	-	-	-	-	-	-	-	-	-	-	-
Center	-	-	-	-	-	-	1.69	1.99	1.33	1.21	1.03
Outlet	-	-	-	-	-	-	1.73	2.19	1.41	1.22	1.41
Visual Observations											
Tray 3 Spray Heights, inches	17	18	10	14	18	16	18-20	16-18	21	20	8
Weepage from Tray 4	none	none	none	none	slight	slight	slight	mod	slight	none	slight
Temperatures, degrees F											
Accumulator	99.0	104.4	106.2	104.5	103.8	106.4	108.2	107.9	101.6	98.7	104.0
Overhead Condensate	88.6	99.5	99.4	96.9	96.1	98.8	96.5	95.5	95.1	93.5	90.9
Overhead Vapor	208.6	209.5	209.0	209.6	209.4	209.5	208.6	208.4	211.2	211.0	208.6
Tray 6 Outlet	211.9	212.7	211.2	212.6	212.9	211.9	211.2	210.6	214.9	214.7	211.6
Tray 5 Outlet	212.2	213.3	212.4	213.7	212.8	213.2	211.4	211.1	215.0	214.9	211.0
Tray 4 Outlet	212.9	214.2	213.3	214.5	213.3	214.0	212.2	212.1	216.0	216.0	211.6
Tray 3 Outlet	213.6	214.9	213.9	215.2	213.8	214.7	212.5	212.5	216.5	216.6	212.2
Tray 2 Outlet	214.7	216.1	213.9	216.0	213.9	215.7	213.4	212.3	217.5	217.3	212.7
Tray 1 Outlet	214.4	215.8	214.6	216.2	214.4	215.5	213.1	213.1	217.4	217.6	212.2
Bottoms	214.2	215.8	214.5	215.9	214.3	215.7	213.1	213.2	217.7	217.4	212.1
Reboiler Vapor	215.2	216.7	215.4	216.8	215.4	216.4	213.9	213.9	218.3	218.2	213.1
Feed	203.0	202.0	194.5	192.4	129.5	202.3	199.2	205.5	201.7	189.7	168.1
Conditions at Tray 3											
Liquid Density, lbs/ft ³	59.7	59.6	59.7	59.6	59.7	59.6	59.7	59.7	59.6	59.6	59.7
Vapor Density, lbs/ft ³	0.0385	0.0394	0.0387	0.0397	0.0386	0.0393	0.0377	0.0377	0.0406	0.0407	0.0375
Liquid Rate, gpm	161	162	80.7	82.5	21.0	162	87.6	167	170	85.7	23.7
Vapor Rate, M lbs/hr	7.46	9.41	7.44	9.17	8.61	9.24	5.92	5.84	12.2	12.2	5.56
Fs, ft/sec (lbs/ft ³) ^{0.5}	0.840	1.05	0.837	1.02	0.968	1.03	0.674	0.665	1.34	1.34	0.634
Capacity Factor, Cs, ft/sec	0.109	0.136	0.108	0.132	0.125	0.133	0.0872	0.0861	0.173	0.173	0.0821
Overall Tray Efficiency, %	37.0	39.0	43.1	39.9	38.4	41.0	42.3	32.6	38.1	33.5	35.6

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TABLE I (S.I Units)
 FRI Distillation Unit Experimental Data
 1.22 Foot Diameter High Pressure Column
 13% Straight Downcomer, 686 inches Tray Spacing
 7.5% Sieve Tray, 12.7 mm Holes on 38.1 mm Triangular Spacing
 50.8 mm by 94.0 mm Outlet Weir, 36.8 mm Downcomer Clearance
 Trace Toluene In Water, Atmospheric Pressure

Run Number	16533	16534	16535	16536	16537	16538	16543	16544	16545	16546	16547
Run Type	L/V	L/V	L/V	L/V	L/V						
L/V	10.3	8.24	5.19	4.31	1.17	8.37	7.09	13.7	6.66	3.36	2.04
Reboiler Duty, Mega Watts	2.15	2.68	2.15	2.64	2.49	2.64	1.71	1.70	3.50	3.57	1.62
Condenser Duty, Mega Watts	2.19	2.72	2.11	2.65	2.48	2.60	1.70	1.68	3.50	3.48	1.58
Overhead Product Rate, kg/sec	0.832	1.13	0.960	1.10	1.02	1.12	0.728	0.742	1.40	1.51	0.644
Bottoms Rate, kg/sec	8.63	8.55	3.86	3.80	0.333	8.13	4.37	9.37	8.67	4.29	0.708
Feed Rate, kg/sec	9.72	9.71	4.89	4.92	1.20	9.69	5.27	10.1	10.1	5.14	1.37
Feed Location	TOP	TOP	TOP	TOP	TOP						
Tower Top Pressure, kPa	106	109	105	108	106	107	102	102	111	111	103
Pressure Drop, mm of Hot Liquid											
Trays 1-6	-	-	-	-	-	-	419	454	699	668	329
Trays 1-3	-	-	-	-	-	-	209	227	351	332	164
Trays 4-6	-	-	-	-	-	-	213	225	348	335	167
Tray 3 Bubblers, mm of Hot Liquid											
Inlet	-	-	-	-	-	-	-	-	-	-	-
Center	-	-	-	-	-	-	42.8	50.4	33.7	30.6	26.3
Outlet	-	-	-	-	-	-	43.8	55.5	35.7	30.9	35.7
Visual Observations											
Tray 3 Spray Heights, mm	482	457	254	356	457	406	457-508	406-457	533	508	203
Weepage from Tray 4	none	none	none	none	slight	slight	slight	mod	slight	none	slight
Temperatures, degrees C											
Accumulator	37.2	40.2	41.2	40.3	39.9	41.3	42.3	42.2	38.7	37.1	40.0
Overhead Condensate	31.4	37.5	37.4	36.0	35.6	37.1	35.8	35.3	35.1	34.2	32.7
Overhead Vapor	98.1	98.6	98.3	98.7	98.5	98.6	98.1	98.0	99.5	99.4	98.1
Tray 6 Outlet	100.0	100.4	99.5	100.3	100.5	99.9	99.6	99.2	101.6	101.5	99.8
Tray 5 Outlet	100.1	100.7	100.2	100.9	100.5	100.7	99.7	99.5	101.7	101.6	99.4
Tray 4 Outlet	100.5	101.2	100.7	101.4	100.7	101.1	100.1	100.1	102.2	102.2	99.8
Tray 3 Outlet	100.9	101.6	101.0	101.8	101.0	101.5	100.3	100.3	102.5	102.6	100.1
Tray 2 Outlet	101.5	102.3	101.1	102.2	101.1	102.1	100.8	100.2	103.0	103.0	100.4
Tray 1 Outlet	101.4	102.1	101.5	102.3	101.3	102.0	100.6	100.6	103.0	103.1	100.1
Bottoms	101.2	102.1	101.4	102.2	101.3	102.0	100.6	100.6	103.1	103.0	100.0
Reboiler Vapor	101.8	102.6	101.9	102.6	101.9	102.4	101.1	101.1	103.5	103.4	100.6
Feed	95.8	94.4	90.3	89.1	54.2	94.6	92.9	96.4	94.3	87.6	75.6
Conditions at Tray 3											
Liquid Density, kg/m ³	956	955	956	955	956	955	956	956	955	955	957
Vapor Density, kg/m ³	0.616	0.631	0.619	0.635	0.619	0.629	0.604	0.604	0.650	0.652	0.600
Liquid Rate, m ³ /hr	36.6	36.8	18.3	18.7	4.78	36.7	19.9	37.9	38.6	19.5	5.38
Vapor Rate, kg/sec	0.948	1.19	0.938	1.15	1.08	1.16	0.746	0.736	1.54	1.54	0.700
Fs, m/sec (kg/m ³) ^{0.5}	1.02	1.28	1.02	1.24	1.18	1.26	0.82	0.81	1.63	1.63	0.77
Capacity Factor, Cs, m/sec	0.0382	0.0414	0.0330	0.0402	0.0382	0.0407	0.0266	0.0262	0.0528	0.0529	0.0250
Overall Tray Efficiency, %	37.8	39.0	43.1	39.9	38.4	41.0	42.3	32.6	38.1	33.5	35.6

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TABLE II (English Units)
FRI Distillation Unit Experimental Data
4 Foot Diameter High Pressure Column
13% Straight Downcomer, 27 inches Tray Spacing
7.5% Sieve Tray, 1/2 inches Holes on 1.5 inches Triangular Spacing
2 inches by 37 inches Outlet Weir, 1.5 inches Downcomer Clearance
Trace Toluene In Water, Atmospheric Pressure

Run Number	16548	16549	16550	16551	16552	16553	16554	16555	16556	16557	16558	16559
Run Type	L/V	FLD*	FLD**									
L/V	1.57	1.27	1.07	13.1	16.6	19.9	4.38	8.53	16.3	5.86	2.23	1.87
Reboiler Duty, MM BTU/hr	7.00	8.98	11.7	12.2	9.55	7.53	9.31	9.23	4.86	13.5	21.1	-
Condenser Duty, MM BTU/hr	6.97	8.97	11.4	11.8	9.53	7.87	9.38	9.04	4.79	13.7	20.5	24.9
Overhead Product Rate, M lbs/hr	6.91	8.51	11.0	11.8	9.51	8.46	9.13	9.18	4.88	13.7	20.4	24.6
Bottoms Rate, M lbs/hr	4.14	2.33	0.910	150	153	146	30.2	73.3	77.3	68.7	29.7	26.0
Feed Rate, M lbs/hr	10.9	11.0	11.9	161	161	147	41.1	79.9	79.9	80.9	47.2	46.9
Feed Location	TOP											
Tower Top Pressure, psia	15.1	15.3	15.9	16.2	15.7	15.3	15.5	15.5	14.8	16.8	18.9	21.5
Pressure Drop, inches of Hot Liquid												
Trays 1-6	15.1	18.1	22.3	27.9	23.9	21.1	20.8	21.8	16.8	30.7	50.5	-
Trays 1-3	7.49	9.05	11.0	14.6	12.4	11.0	10.3	10.9	8.48	15.4	24.6	34.2
Trays 4-6	7.56	9.05	11.1	13.6	11.4	10.0	10.4	10.8	8.15	15.4	25.7	47.4
Tray 3 Bubblers, inches of Hot Liquid												
Inlet	-	-	-	-	-	-	-	-	-	-	-	-
Center	0.895	0.855	0.755	1.45	1.83	2.14	1.38	1.62	2.07	0.955	0.215	0.366
Outlet	1.23	1.00	1.08	1.87	2.08	2.39	1.47	1.67	2.68	-	0.386	0.476
Visual Observations												
Tray 3 Spray Heights, inches	20-22	24	27	24	18	14	22-24	24	15	27	27	27
Weepage from Tray 4	none	none	none	slight	none	slight	none	none	mod	none	none	none
Temperatures, degrees F												
Accumulator	105.2	103.4	103.5	99.0	103.2	104.9	104.9	106.7	105.4	104.0	101.6	104.1
Overhead Condensate	95.2	95.6	97.0	94.0	96.1	96.1	97.8	99.3	89.8	100.0	98.6	101.9
Overhead Vapor	209.4	210.1	211.0	210.9	209.8	209.1	209.9	209.7	208.2	212.3	217.7	221.6
Tray 6 Outlet	212.3	213.2	214.9	213.6	212.4	211.4	212.7	212.0	210.1	215.2	223.4	229.3
Tray 5 Outlet	211.9	213.0	214.5	214.6	212.8	211.7	213.3	213.0	210.6	216.6	224.2	230.3
Tray 4 Outlet	212.5	213.6	215.4	215.9	213.9	212.7	214.1	214.1	211.6	217.6	225.4	232.0
Tray 3 Outlet	212.9	214.0	215.8	216.6	214.6	213.3	214.6	214.6	212.1	218.4	226.3	233.4
Tray 2 Outlet	213.1	214.9	216.7	217.6	215.5	214.2	214.8	215.4	212.9	219.4	226.9	234.8
Tray 1 Outlet	213.2	214.5	216.4	217.5	215.4	214.0	215.3	215.3	212.7	219.3	227.7	235.1
Bottoms	213.2	214.5	216.3	217.6	215.4	213.9	215.3	215.4	212.6	219.6	228.4	235.9
Reboiler Vapor	214.1	215.5	217.4	218.4	216.2	214.9	216.1	216.1	213.5	220.2	228.8	236.4
Feed	158.0	140.7	129.7	209.1	208.8	209.4	192.0	203.1	206.2	200.6	175.8	169.9
Conditions at Tray 3												
Liquid Density, lbs/ft ³	59.7	59.7	59.6	59.6	59.6	59.7	59.7	59.7	59.7	59.5	59.3	59.1
Vapor Density, lbs/ft ³	0.0380	0.0388	0.0401	0.0406	0.0392	0.0383	0.0392	0.0392	0.0374	0.0420	0.0484	0.0548
Liquid Rate, gpm	23.0	24.1	26.5	337	336	305	86.7	167	167	170	102	101
Vapor Rate, M lbs/hr	7.00	9.06	11.8	12.3	9.67	7.34	9.48	9.38	4.89	13.8	21.7	25.8
Fs, ft/sec (lbs/ft ³) ^{0.5}	0.793	1.02	1.30	1.35	1.08	0.830	1.06	1.05	0.559	1.49	2.18	2.43
Capacity Factor, Cs, ft/sec	0.103	0.132	0.169	0.175	0.140	0.107	0.137	0.136	0.0723	0.193	0.283	0.316
Overall Tray Efficiency, %	40.2	37.3	31.4	32.1	35.6	35.3	34.8	39.1	32.8	39.4	-	-

* NEAR FLOOD
** ESTIMATED TO BE ABOVE ACTUAL FLOOD (6 FOOT SPRAY HEIGHT ON TOP TRAY)

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TABLE II (S.I Units)
FRI Distillation Unit Experimental Data
1.22 Foot Diameter High Pressure Column
13% Straight Downcomer, 686 inches Tray Spacing
7.5% Sieve Tray, 12.7 mm Holes on 38.1 mm Triangular Spacing
50.8 mm by 940 mm Outlet Weir, 38.1 mm Downcomer Clearance
Trace Toluene In Water, Atmospheric Pressure

Run Number	16548	16549	16550	16551	16552	16553	16554	16555	16556	16557	16558	16559
Run Type	L/V	L/V	L/V	L/V	L/V	L/V	L/V	L/V	L/V	L/V	FLD*	FLD**
L/V	1.57	1.27	1.07	13.1	16.6	19.9	4.38	8.53	16.3	5.86	2.23	1.87
Reboiler Duty, Mega Watts	2.85	2.63	3.43	3.57	2.80	2.21	2.73	2.70	1.42	3.96	6.18	-
Condenser Duty, Mega Watts	2.84	2.63	3.33	3.46	2.79	2.31	2.75	2.65	1.40	4.01	6.01	7.29
Overhead Product Rate, kg/sec	0.871	1.07	1.38	1.49	1.20	1.07	1.15	1.16	0.615	1.73	2.57	3.10
Bottoms Rate, kg/sec	0.521	0.294	0.115	18.9	19.3	18.4	3.80	9.24	9.73	8.66	3.74	3.28
Feed Rate, kg/sec	1.37	1.38	1.49	20.2	20.2	18.6	5.18	10.1	10.1	10.2	5.94	5.91
Feed Location	TOP	TOP	TOP	TOP	TOP	TOP	TOP	TOP	TOP	TOP	TOP	TOP
Tower Top Pressure, kPa	184	106	110	112	108	105	107	107	102	116	130	148
Pressure Drop, mm of Hot Liquid												
Trays 1-6	382	460	566	707	606	536	529	554	427	780	1282	-
Trays 1-3	190	230	279	370	316	279	262	278	216	391	625	869
Trays 4-6	192	230	282	346	290	254	265	274	207	391	652	1204
Tray 3 Bubblers, mm of Hot Liquid												
Inlet	-	-	-	-	-	-	-	-	-	-	-	-
Center	22.7	21.7	19.2	36.7	46.4	54.2	34.9	41.0	52.5	24.3	5.46	9.29
Outlet	31.1	25.3	27.3	47.4	52.7	60.6	37.2	42.3	68.0	-	9.80	12.1
Visual Observations												
Tray 3 Spray Heights, mm	508-559	610	686	610	457	356	559-610	610	381	686	686	686
Weepage from Tray 4	none	none	none	slight	none	slight	none	none	mod	none	none	none
Temperatures, degrees C												
Accumulator	40.7	39.7	39.7	37.2	39.5	40.5	40.5	41.5	40.8	40.0	38.6	40.1
Overhead Condensate	35.1	35.3	36.1	34.4	35.6	35.6	36.6	37.4	32.1	37.8	37.0	38.8
Overhead Vapor	98.5	99.0	99.4	99.4	98.8	98.4	98.8	98.7	97.9	100.2	103.1	105.3
Tray 6 Outlet	108.2	100.7	101.6	100.9	100.2	99.7	100.4	100.0	99.0	101.8	106.4	109.6
Tray 5 Outlet	99.9	100.6	101.4	101.5	100.5	99.8	100.7	100.6	99.2	102.5	106.8	110.2
Tray 4 Outlet	108.3	100.9	101.9	102.2	101.1	100.4	101.1	101.1	99.8	103.1	107.4	111.1
Tray 3 Outlet	108.5	101.1	102.1	102.5	101.4	100.7	101.4	101.4	100.1	103.5	108.0	111.9
Tray 2 Outlet	108.6	101.6	102.6	103.1	101.9	101.2	101.5	101.9	100.5	104.1	108.3	112.7
Tray 1 Outlet	108.7	101.4	102.5	103.1	101.9	101.1	101.8	101.8	100.4	104.1	108.7	112.9
Bottoms	108.7	101.4	102.4	103.1	101.9	101.1	101.8	101.9	100.4	104.2	109.1	113.3
Reboiler Vapor	104.2	102.0	103.0	103.6	102.4	101.6	102.3	102.3	100.8	104.6	109.3	113.6
Feed	78.0	60.4	54.3	98.4	98.2	98.6	88.9	95.1	96.8	93.7	79.9	76.6
Conditions at Tray 3												
Liquid Density, kg/m ³	956	956	955	955	955	956	956	956	957	954	950	947
Vapor Density, kg/m ³	0.609	0.621	0.642	0.651	0.628	0.613	0.627	0.627	0.600	0.673	0.776	0.878
Liquid Rate, m ³ /hr	5.21	5.46	6.02	76.5	76.3	69.3	19.7	38.0	37.9	38.5	23.1	23.0
Vapor Rate, kg/sec	0.882	1.14	1.49	1.55	1.22	0.925	1.19	1.18	0.616	1.74	2.74	3.25
Fs, m/sec (kg/m ³) ^{0.5}	0.968	1.24	1.59	1.65	1.32	1.01	1.29	1.28	0.682	1.82	2.66	2.97
Capacity Factor, Cs, m/sec	0.0813	0.0401	0.0515	0.0534	0.0426	0.0327	0.0418	0.0414	0.0220	0.0589	0.0863	0.0965
Overall Tray Efficiency, %	40.2	37.3	31.4	32.1	35.6	35.3	34.8	39.1	32.8	39.4	-	-

* NEAR FLOOD

** ESTIMATED TO BE ABOVE ACTUAL FLOOD (6 FOOT SPRAY HEIGHT ON TOP TRAY)

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TABLE III
FRI DISTILLATION UNIT EXPERIMENTAL DATA
TOLUENE/WATER ANALYSIS BY VAPOR PHASE CHROMATOGRAPHY
WITH PHOTOIONIZATION DETECTOR
LIQUID COMPOSITION, MOLE PERCENT TOLUENE

Run Number	16533	16534	16535A	16535B
Feed	2.809 E-3	2.78 E-3	2.533 E-3	3.694 E-3
Reflux	2.55 E-3	2.46 E-3	2.518 E-3	3.269 E-3
T-6 Inlet	3.233 E-3	2.626 E-3	2.288 E-3	3.532 E-3
T-6 Center	1.243 E-3	1.311 E-3	7.942 E-4	8.59 E-4
T-6 Outlet	4.866 E-4	2.293 E-4	8.611 E-4	8.173 E-4
T-5 Center	2.610 E-4	9.159 E-5	6.58 E-5	2.844 E-4
T-5 Outlet	6.98 E-5	6.32 E-5	2.383 E-5	9.488 E-5
T-4 Outlet	8.152 E-6	2.292 E-6	1.012 E-6	1.487 E-6
T-3 Outlet	5.09 E-7	3.858 E-7	1.580 E-7	3.650 E-7
T-2 Outlet	3.32 E-7	*	*	*
T-1 Outlet	*	*	*	*
Reb. Liquid	*	*	*	*

	16536A	16536B	16537A	16537B	16538A	16538B
Feed	3.618 E-3	2.587 E-3	2.769 E-3	1.788 E-3	2.32 E-3	3.55 E-3
Reflux	3.33 E-3	2.197 E-3	2.094 E-3	1.78 E-3	1.71 E-3	2.14 E-3
T-6 Inlet	3.932 E-3	2.381 E-3	2.112 E-3	1.967 E-3	1.63 E-3	1.38 E-3
T-6 Center	1.918 E-3	1.380 E-3	9.674 E-4	6.357 E-4	8.26 E-4	6.39 E-4
T-6 Outlet	9.80 E-4	1.091 E-3	8.315 E-5	2.62 E-5	6.114 E-4	7.414 E-4
T-5 Center	1.515 E-4	1.477 E-4	3.83 E-5	7.60 E-6	3.26 E-4	3.643 E-4
T-5 Outlet	1.044 E-4	1.10 E-4	8.34 E-6	2.205 E-6	6.792 E-5	5.33 E-5
T-4 Outlet	5.693 E-6	1.311 E-6	2.89 E-7	3.90 E-8	4.98 E-6	5.435 E-6
T-3 Outlet	1.062 E-6	1.157 E-7	*	*	6.00 E-7	1.567 E-6
T-2 Outlet	*	*	*	*	*	3.581 E-7
T-1 Outlet	*	*	*	*	*	*
Reb. Liquid	*	*	*	*	*	*

	16543A	16543B	16544A	16544B	16545A	16545B
Feed	1.122 E-3	1.512 E-3	1.807 E-3	1.009 E-3	6.632 E-4	7.707 E-4
Reflux	1.019 E-3	9.840 E-4	1.453 E-3	8.864 E-4	6.587 E-4	2.159 E-4
T-6 Inlet	2.204 E-4	5.881 E-4	7.644 E-4	9.876 E-4	6.532 E-4	4.606 E-4
T-6 Center	6.237 E-5	2.662 E-5	4.914 E-4	3.504 E-4	3.725 E-4	1.193 E-4
T-6 Outlet	2.974 E-5	5.845 E-5	2.030 E-4	1.976 E-4	1.050 E-4	4.384 E-5
T-5 Center	8.013 E-6	-	2.561 E-5	-	-	-
T-5 Outlet	2.813 E-6	5.53 E-6	3.274 E-5	6.904 E-5	2.643 E-5	4.631 E-6
T-4 Outlet	1.188 E-7	4.024 E-7	3.751 E-6	4.208 E-6	1.113 E-6	1.188 E-8
T-3 Outlet	*	1.355 E-7	1.101 E-6	1.263 E-6	2.228 E-7	4.301 E-8
T-2 Outlet	*	*	1.107 E-7	1.927 E-7	*	*
T-1 Outlet	*	*	*	3.923 E-8	*	*
Reb. Liquid	*	*	*	1.267 E-8	*	*

	16546A	16546B	16547A	16547B	16548A	16548B
Feed	1.526 E-3	3.037 E-3	1.06 E-3	9.611 E-4	1.223 E-3	3.201 E-3
Reflux	5.488 E-4	4.707 E-4	7.78 E-4	7.73 E-4	-	8.170 E-4
T-6 Inlet	4.743 E-5	4.847 E-5	7.55 E-4	8.713 E-4	1.359 E-3	7.810 E-4
T-6 Center	2.866 E-5	1.105 E-5	1.771 E-4	7.961 E-5	8.363 E-5	8.954 E-5
T-6 Outlet	-	1.864 E-5	-	-	4.611 E-5	4.085 E-5
T-5 Center	5.072 E-7	2.759 E-6	2.946 E-5	1.093 E-5	1.776 E-5	2.757 E-5
T-5 Outlet	2.849 E-7	-	2.738 E-6	4.991 E-7	3.383 E-6	3.547 E-6
T-4 Outlet	8.509 E-8	2.013 E-7	-	4.121 E-7	3.449 E-7	1.107 E-7
T-3 Outlet	*	2.492 E-8	2.701 E-8	4.635 E-8	*	*
T-2 Outlet	*	*	*	*	*	*
T-1 Outlet	*	*	*	*	*	*
Reb. Liquid	*	*	*	*	*	*

*Liquid composition below minimum detectable limit.

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TABLE III (CONT'D)
FRI DISTILLATION UNIT EXPERIMENTAL DATA
TOLUENE/WATER ANALYSIS BY VAPOR PHASE CHROMATOGRAPHY
WITH PHOTONIZATION DETECTOR
LIQUID COMPOSITION, MOLE PERCENT TOLUENE

	16549A	16549B	16550A	16550B	16551A	16551B
Feed	2.031 E-3	8.492 E-4	7.945 E-4	7.173 E-4	2.452 E-4	6.294 E-4
Reflux	8.169 E-4	6.656 E-4	5.231 E-4	5.965 E-4	3.374 E-4	5.855 E-4
T-6 Inlet	7.188 E-4	6.459 E-4	5.441 E-4	5.011 E-4	3.063 E-4	5.188 E-4
T-6 Center	2.882 E-4	1.807 E-4	2.630 E-4	2.914 E-4	1.353 E-4	6.932 E-4
T-6 Outlet	3.511 E-5	4.92 E-5	4.60 E-5	4.224 E-5	1.017 E-4	4.046 E-4
T-5 Center	3.077 E-5	1.622 E-5	1.784 E-5	7.99 E-6	2.51 E-5	7.367 E-5
T-5 Outlet	4.879 E-6	3.752 E-6	8.033 E-6	6.365 E-6	1.940 E-5	8.684 E-5
T-4 Outlet	1.169 E-7	2.291 E-7	1.603 E-7	3.368 E-7	3.476 E-6	6.526 E-6
T-3 Outlet	1.301 E-7	*	3.392 E-8	5.194 E-8	7.359 E-7	7.365 E-7
T-2 Outlet	*	*	*	*	1.109 E-7	1.309 E-7
T-1 Outlet	*	*	*	*	9.28 E-8	-
Reb. Liquid	*	*	*	*	1.791 E-8	1.899 E-8

	16552A	16552B	16553A	16553B	16554A	16554B
Feed	6.586 E-4	5.088 E-4	1.577 E-3	2.017 E-3	7.967 E-4	1.415 E-3
Reflux	5.191 E-4	5.280 E-4	6.431 E-4	7.136 E-4	5.045 E-4	5.683 E-4
T-6 Inlet	5.396 E-4	4.601 E-4	3.130 E-4	4.534 E-4	6.030 E-4	5.706 E-4
T-6 Center	4.434 E-4	4.267 E-4	2.864 E-4	8.792 E-4	3.119 E-4	3.999 E-4
T-6 Outlet	3.096 E-4	2.655 E-4	1.210 E-4	1.479 E-4	1.792 E-4	2.125 E-4
T-5 Center	3.788 E-5	2.625 E-5	3.113 E-5	2.397 E-5	1.414 E-5	1.552 E-5
T-5 Outlet	4.926 E-5	4.593 E-5	2.003 E-5	3.267 E-5	5.191 E-6	2.901 E-6
T-4 Outlet	4.985 E-6	4.523 E-6	4.542 E-6	4.231 E-6	4.278 E-7	4.880 E-7
T-3 Outlet	5.918 E-7	8.487 E-7	1.362 E-6	1.229 E-6	7.736 E-8	2.543 E-7
T-2 Outlet	1.504 E-7	2.574 E-7	4.494 E-7	3.694 E-7	*	3.250 E-8
T-1 Outlet	6.808 E-8	4.813 E-8	5.783 E-8	3.029 E-7	*	*
Reb. Liquid	6.560 E-9	1.108 E-8	*	6.109 E-8	*	*

	16555A	16555B	16556A	16556B	16557A	16557B
Feed	5.292 E-4	2.831 E-4	4.276 E-4	8.836 E-4	4.526 E-4	3.003 E-4
Reflux	3.654 E-4	3.713 E-4	2.161 E-4	6.454 E-4	3.777 E-4	4.908 E-4
T-6 Inlet	3.144 E-4	3.604 E-4	5.701 E-4	5.691 E-4	4.143 E-4	4.837 E-5
T-6 Center	2.208 E-4	3.152 E-4	4.427 E-4	3.299 E-4	5.045 E-4	6.772 E-5
T-6 Outlet	3.605 E-4	2.722 E-4	2.221 E-4	1.307 E-4	2.359 E-4	3.391 E-4
T-5 Center	6.613 E-5	5.407 E-5	1.735 E-4	-	2.441 E-5	2.185 E-5
T-5 Outlet	9.866 E-5	1.347 E-4	2.418 E-5	7.127 E-6	3.682 E-5	2.723 E-5
T-4 Outlet	3.545 E-6	4.683 E-5	1.256 E-5	1.659 E-6	1.127 E-6	-
T-3 Outlet	2.623 E-7	3.003 E-7	1.760 E-6	3.100 E-7	1.033 E-7	3.119 E-7
T-2 Outlet	3.433 E-8	2.28 E-8	3.227 E-7	1.501 E-7	*	8.573 E-9
T-1 Outlet	*	*	*	3.830 E-8	*	*
Reb. Liquid	*	*	*	*	*	*

*Liquid composition below minimum detectable limit.

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TABLE IV
COMPARISON OF EXPERIMENTAL EFFICIENCIES WITH EFFICIENCIES
FROM TWO-FILM MODELS - FRI AND AICHE

RUN NO.	16533	16534	16535	16536	16537	16538	16543	16544	16545	16546
PRESSURE, PSIA	15.40	15.82	15.25	15.59	15.44	15.54	14.82	14.79	16.12	16.06
TEMP, °F	213.6	214.9	213.9	215.2	213.8	214.7	212.5	212.5	216.5	216.5
LIQUID RATE, GPM	161.3	162.1	80.7	82.5	21.0	161.6	87.6	166.9	170.0	85.7
VAPOR RATE, FS	0.840	1.048	0.837	1.017	0.968	1.030	0.674	0.665	1.338	1.339
EQUILIBRIUM RATIO, K _{TOL}	2379	2355	2392	2359	2382	2368	2424	2424	2340	2344
LAMBDA, K V/L	229.9	285.8	460.9	547.3	2036	282.9	341.9	177.1	351.4	697.6
ADDITIONAL PROPERTIES										
LIQ DIFF, 10 ⁻⁴ FT ² /HR	1.54	1.57	1.56	1.57	1.55	1.57	1.53	1.53	1.59	1.59
VAP DIFF, CM ² /S	0.106	0.103	0.105	0.103	0.106	0.103	0.108	0.108	0.101	0.101
LIQ VISC, CP	0.277	0.274	0.276	0.274	0.276	0.275	0.278	0.278	0.272	0.272
VAP VISC, CP	0.0121	0.0121	0.0121	0.0121	0.0121	0.0121	0.0120	0.0120	0.0121	0.0121
VAP SCHMIDT NO.	1.86	1.86	1.86	1.85	1.85	1.87	1.84	1.84	1.84	1.84
FRI PARAMETERS										
LIQ HOLDUP, HLE, IN	1.79	1.57	1.44	1.27	0.97	1.59	1.68	2.06	1.37	1.06
LIQ VOLUME FRAC	0.416	0.338	0.418	0.348	0.365	0.344	0.501	0.507	0.261	0.261
LIQ RESIDENCE TIME, SEC	3.519	3.076	5.657	4.888	14.58	3.114	6.081	3.910	2.556	3.921
VAP RESIDENCE TIME	0.0256	0.0183	0.0207	0.0152	0.0120	0.0187	0.0297	0.0369	0.0127	0.0098
VAP TRANSFER UNIT, NG	1.39	1.39	1.25	1.25	1.07	1.39	1.27	1.40	1.41	1.24
LIQ TRANSFER UNIT, NL	0.88	0.98	1.11	1.21	1.99	0.97	0.97	0.77	1.09	1.35
OVERALL TRANS UNIT, NOG	.0038	.0034	.0024	.0022	.0010	.0034	.0028	.0043	.0031	.0019
AICHE PARAMETERS										
LIQ HOLDUP, IN	2.442	2.258	1.898	1.746	1.372	2.270	2.094	2.641	2.045	1.471
LIQ RESIDENCE TIME, SEC	4.365	4.015	6.780	6.097	18.804	4.050	6.890	4.561	3.468	4.947
EDDY DIFFUSIVITY	0.0744	0.0819	0.0428	0.0520	0.0303	6.0866	0.0377	0.0662	0.1119	0.0709
PECLET NO.	19.24	17.71	21.55	19.71	10.99	17.81	24.08	20.70	16.10	17.81
VAPOR TRANSFER UNIT, NG	1.329	1.273	0.914	0.874	0.569	1.272	1.002	1.416	1.236	0.799
LIQ TRANSFER UNIT, NL	2.498	2.701	3.895	4.015	11.887	2.692	3.414	2.241	2.811	4.011
OVERALL TRANS UNIT, NOG	.01084	.00943	.00839	.00730	.00578	.00949	.00990	.01261	.00797	.00571
POINT EFFICIENCY										
FRI, %	0.38	0.34	0.24	0.22	0.10	0.34	0.28	0.43	0.31	0.19
AICHE, %	1.08	0.94	0.84	0.73	0.58	0.94	0.98	1.25	0.79	0.57
MURPHREE VAP TRAY EFFICIENCY										
FRI, %	0.61	0.58	0.44	0.43	0.31	0.58	0.47	0.65	0.56	0.41
AICHE, %	3.59	3.41	5.96	5.35	71.71	3.42	5.61	3.71	2.98	4.02
EXPERIMENTAL, %	2.83	2.84	2.84	2.08	0.87	3.24	3.17	2.50	2.38	1.14
MURPHREE LIQ TRAY EFFICIENCY										
FRI, %	58.5	62.6	67.2	70.3	86.4	62.3	62.0	53.6	66.4	74.0
AICHE, %	89.5	90.9	96.7	96.9	100.0	90.9	95.3	87.2	91.5	96.7
EXPERIMENTAL, %	87.0	89.3	93.1	92.1	94.7	90.4	91.8	82.0	89.5	89.0
OVERALL TRAY EFFICIENCY										
FRI, %	16.0	17.3	18.1	19.2	26.1	17.2	16.5	14.7	18.5	20.5
AICHE, %	40.8	41.9	54.6	54.0	95.6	41.8	51.5	39.0	41.5	51.4
EXPERIMENTAL, %	37.0	39.0	43.1	39.9	38.4	38.7	42.3	32.6	38.1	33.5

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TABLE IV (CONT'D)
COMPARISON OF EXPERIMENTAL EFFICIENCIES WITH EFFICIENCIES
FROM TWO-FILM MODELS - FRI AND AICHE

RUN NO.	16547	16548	16549	16550	16551	16552	16553	16554	16555	16556	16557
PRESSURE, PSIA	14.92	15.07	15.33	15.95	16.20	15.68	15.27	15.52	15.48	14.81	16.79
TEMP, °F	212.2	212.9	214.0	215.8	216.6	214.6	213.3	214.6	214.6	212.1	218.4
LIQUID RATE, GPM	23.7	23.0	24.1	26.5	337	336	305	86.7	167.4	166.9	169.6
VAPOR RATE, FS	0.634	0.793	1.017	1.303	1.353	1.080	0.830	1.059	1.048	0.559	1.490
EQUILIBRIUM RATIO, KTOL	2417	2407	2390	2350	2334	2367	2391	2375	2377	2424	2299
LAMBDA, K V/L	1185	1533	1882	2196	178.9	142.4	120.2	542.2	278.7	148.4	392.3
ADDITIONAL PROPERTIES											
LIQ DIFF, 10 ⁻⁴ FT ² /HR	1.53	1.54	1.55	1.58	1.59	1.57	1.54	1.57	1.57	1.53	1.61
VAP DIFF, CM ² /S	0.109	0.107	0.106	0.102	0.101	0.104	0.107	0.104	0.104	0.109	0.098
LIQ VISC, CP	0.279	0.278	0.276	0.273	0.272	0.275	0.277	0.275	0.277	0.276	0.269
VAP VISC, CP	0.0120	0.0120	0.0121	0.0121	0.0121	0.0121	0.0121	0.0121	0.0121	0.0120	0.0122
VAP SCHMIDT NO.	1.83	1.84	1.84	1.85	1.84	1.85	1.84	1.85	1.85	1.84	1.85
FRI PARAMETERS											
LIQ HOLDUP, HLE, IN	1.34	1.14	0.95	0.79	1.85	2.10	2.31	1.26	1.59	2.24	1.27
LIQ VOLUME FRAC	0.525	0.438	0.349	0.269	0.258	0.328	0.422	0.335	0.339	0.576	0.230
LIQ RESIDENCE TIME, SEC	17.91	15.77	12.54	9.418	1.739	1.981	2.403	4.602	3.017	4.262	2.379
VAP RESIDENCE TIME	0.0250	0.0172	0.0113	0.0074	0.0169	0.0236	0.0335	0.0144	0.0185	0.0476	0.0107
VAP TRANSFER UNIT, NG	1.12	1.10	1.08	1.06	1.64	1.63	1.58	1.25	1.41	1.39	1.40
LIQ TRANSFER UNIT, NL	1.59	1.77	1.93	2.04	0.91	0.80	0.72	1.21	0.97	0.70	1.15
OVERALL TRANS UNIT, NOG	0.0013	0.0012	0.0010	0.0009	0.0050	0.0056	0.0059	0.0022	0.0035	0.0047	0.0029
AICHE PARAMETERS											
LIQ HOLDUP, IN	1.697	1.545	1.347	1.101	3.167	3.410	3.429	1.735	2.293	2.738	1.904
LIQ RESIDENCE TIME, SEC	20.62	19.42	16.15	11.98	2.709	2.925	3.238	5.766	3.949	4.729	3.235
EDDY DIFFUSIVITY	0.0190	0.0242	0.0331	0.0463	0.2225	0.1951	0.1509	0.0562	0.0907	0.0600	0.1217
PECLET NO.	15.98	13.30	11.70	11.28	10.37	10.95	12.79	19.30	17.45	22.04	15.87
VAPOR TRANSFER UNIT, NG	0.684	0.632	0.572	0.501	2.099	2.167	2.086	0.883	1.304	1.447	1.187
LIQ TRANSFER UNIT, NL	9.846	10.70	10.57	9.484	2.214	2.011	1.838	3.908	2.657	2.098	2.866
OVERALL TRANS UNIT, NOG	0.0021	0.00690	0.00556	0.00428	0.0124	0.0142	0.0154	0.00714	0.00951	0.0141	0.00729
POINT EFFICIENCY											
FRI, %	0.13	0.12	0.10	0.09	0.50	0.56	0.59	0.22	0.35	0.47	0.29
AICHE, %	0.82	0.69	0.55	0.43	1.23	1.41	1.52	0.71	0.95	1.40	0.73
MURPHREE VAP TRAY EFFICIENCY											
FRI, %	0.33	0.32	0.31	0.30	0.82	0.86	0.87	0.43	0.58	0.68	0.55
AICHE, %	82.8	75.7	47.4	22.92	3.13	3.31	3.41	4.91	3.35	3.89	2.79
EXPERIMENTAL, %	0.97	1.18	0.83	0.47	2.41	2.55	2.88	1.47	2.89	2.82	2.43
MURPHREE LIQ TRAY EFFICIENCY											
FRI, %	79.6	83.0	85.5	86.9	59.6	55.4	51.2	70.1	62.0	50.4	68.4
AICHE, %	100.0	100.0	99.9	99.8	85.1	82.8	80.8	96.6	90.6	85.6	91.8
EXPERIMENTAL, %	92.0	94.8	94.0	91.1	81.5	78.8	78.1	89.0	89.3	81.1	90.7
OVERALL TRAY EFFICIENCY											
FRI, %	22.4	24.1	25.6	26.4	17.3	16.1	14.8	19.1	17.1	13.9	19.2
AICHE, %	97.3	96.2	90.1	80.9	36.2	34.9	33.8	52.7	41.4	38.1	41.4
EXPERIMENTAL, %	35.6	40.2	37.3	31.4	32.1	30.8	31.1	34.8	39.1	32.8	39.4

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TABLE V
PROCESS AND FROTH DENSITIES
TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION ABOVE TRAY-4		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION		
	inches	mm	Low		High		Average		Low	High	Average
			lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³			
Run : 16533	40.90	1039	0.006	0.1	0.040	0.6	0.029	0.5	-0.001	0.000	-0.000
	39.00	991	0.058	0.9	0.090	1.4	0.069	1.1	0.000	0.001	0.001
Horizontal Position: 0 0	inch mm	37.00 940	0.131	2.1	0.169	2.7	0.148	2.4	0.002	0.002	0.002
		35.00 889	0.621	9.9	0.656	10.5	0.639	10.2	0.010	0.010	0.010
		33.00 838	3.344	53.6	3.615	57.9	3.518	56.4	0.055	0.060	0.058
		31.00 787	113.440	215.3	13.867	222.1	13.635	218.4	0.225	0.232	0.228
		30.00 762	118.579	297.6	18.883	302.5	18.771	300.7	0.311	0.316	0.314
		29.00 737	123.974	384.0	24.157	387.0	24.055	385.3	0.401	0.404	0.403
Temperature : deg. F deg. C		28.25 718	126.270	420.8	26.770	428.8	26.504	424.6	0.440	0.448	0.444
		26.00 660	3.482	55.8	3.695	59.2	3.615	57.9	0.058	0.061	0.060
Tray 4 : 212.5 100.3		24.00 610					-0.019	-0.3			-0.001
		22.00 559					-0.017	-0.3			-0.001
		20.00 508					-0.025	-0.4			-0.001
Density : lb/ft ³ kg/m ³		18.00 457	0.002	0.0	0.031	0.5	0.013	0.2	-0.001	-0.000	-0.000
		16.00 406					-0.038	-0.6			-0.001
Liquid : 59.71 956		14.00 356	-0.031	-0.5	0.000	0.0	-0.015	-0.2	-0.001	-0.001	-0.001
Vapor : 0.0377 0.604		12.00 305					-0.027	-0.4			-0.001
		10.00 254					-0.031	-0.5			-0.001
		8.00 203	0.573	9.2	0.619	9.9	0.600	9.6	0.009	0.010	0.009
		6.00 152	4.045	64.8	4.613	73.9	4.263	68.3	0.067	0.077	0.071
		4.00 102	13.584	217.6	14.124	226.3	13.879	222.3	0.227	0.236	0.232
		3.00 76	19.391	310.6	19.675	315.2	19.581	313.7	0.324	0.329	0.328
		2.00 51	25.205	403.7	25.338	405.9	25.255	404.5	0.422	0.424	0.423
		1.25 32	27.745	444.4	27.851	446.1	27.804	445.4	0.464	0.466	0.465
Run : 16533	40.90	1039	0.000	0.0	0.040	0.6	0.017	0.3	-0.001	0.000	-0.000
	39.00	991	0.008	0.1	0.048	0.8	0.028	0.4	-0.001	0.000	-0.000
Horizontal Position: 6 152	inch mm	37.00 940	0.110	1.8	0.167	2.7	0.141	2.3	0.001	0.002	0.002
		35.00 889	1.004	16.1	1.082	17.3	1.029	16.5	0.016	0.018	0.017
		33.00 838	6.137	98.3	6.883	110.3	6.510	104.3	0.102	0.115	0.108
		31.00 787	16.312	261.3	16.770	268.6	16.501	264.3	0.273	0.280	0.276
		30.00 762	20.391	326.6	20.754	332.4	20.527	328.8	0.341	0.347	0.343
		29.00 737	23.874	382.4	24.142	386.7	23.964	383.9	0.400	0.404	0.401
Temperature : deg. F deg. C		28.25 718	24.546	393.2	24.824	397.6	24.693	395.5	0.411	0.415	0.413
		26.00 660	1.777	28.5	1.927	30.9	1.845	29.5	0.029	0.032	0.030
Tray 4 : 212.6 100.4		24.00 610					-0.027	-0.4			-0.001
		22.00 559					-0.025	-0.4			-0.001
		20.00 508					-0.021	-0.3			-0.001
Density : lb/ft ³ kg/m ³		18.00 457					-0.033	-0.5			-0.001
		16.00 406					-0.023	-0.4			-0.001
Liquid : 59.70 956		14.00 356					-0.023	-0.4			-0.001
Vapor : 0.0377 0.605		12.00 305	-0.002	-0.0	0.029	0.5	0.014	0.2	-0.001	-0.000	-0.000
		10.00 254					-0.048	-0.8			-0.001
		8.00 203	1.065	17.1	1.152	18.4	1.110	17.8	0.017	0.019	0.018
		6.00 152	6.185	99.1	7.079	113.4	6.642	106.4	0.103	0.118	0.111
		4.00 102	17.068	273.4	17.693	283.4	17.350	277.9	0.285	0.296	0.290
		3.00 76	21.658	346.9	21.967	351.9	21.773	348.8	0.362	0.368	0.364
		2.00 51	23.582	377.8	23.751	380.5	23.665	379.1	0.395	0.397	0.396
		1.25 32	23.302	373.3	23.405	374.9	23.353	374.1	0.390	0.392	0.391
Run : 16533	40.90	1039	-0.008	-0.1	0.002	0.0	-0.001	-0.0	-0.001	-0.001	-0.001
	39.00	991	0.169	2.7	0.250	4.0	0.208	3.3	0.002	0.004	0.003
Horizontal Position: 14 356	inch mm	37.00 940	0.142	2.3	0.208	3.3	0.180	2.9	0.002	0.003	0.002
		35.00 889	1.800	28.8	1.890	30.3	1.859	29.8	0.030	0.031	0.031
		33.00 838	5.497	88.1	5.630	90.2	5.538	88.7	0.091	0.094	0.092
		31.00 787	14.178	227.1	14.457	231.6	14.274	228.6	0.237	0.242	0.239
		30.00 762	21.531	344.9	21.892	350.7	21.657	346.9	0.360	0.366	0.362
		29.00 737	30.425	487.4	30.608	490.3	30.502	488.6	0.509	0.512	0.511
Temperature : deg. F deg. C		28.25 718	33.113	530.4	33.263	532.8	33.165	531.3	0.554	0.557	0.555
		26.00 660	1.777	28.5	1.928	30.9	1.850	29.6	0.029	0.032	0.030
Tray 4 : 212.6 100.3		24.00 610					-0.019	-0.3			-0.001
		22.00 559					-0.015	-0.2			-0.001
		20.00 508					-0.030	-0.5			-0.001
Density : lb/ft ³ kg/m ³		18.00 457					-0.019	-0.3			-0.001
		16.00 406					-0.034	-0.6			-0.001
Liquid : 59.71 956		14.00 356					-0.026	-0.4			-0.001
Vapor : 0.0377 0.605		12.00 305	-0.023	-0.4	0.029	0.5	0.0091	0.1	-0.001	-0.000	-0.000
		10.00 254					-0.032	-0.5			-0.001
		8.00 203	0.433	6.9	0.488	7.8	0.466	7.5	0.007	0.008	0.007
		6.00 152	3.232	51.8	3.642	58.3	3.420	54.8	0.054	0.060	0.057
		4.00 102	13.763	220.5	14.761	236.4	14.277	228.7	0.230	0.247	0.239
		3.00 76	18.925	303.2	19.287	308.9	19.101	306.0	0.317	0.323	0.319
		2.00 51	22.419	359.1	22.996	368.4	22.858	366.1	0.375	0.385	0.382
		1.25 32	25.157	403.0	25.386	406.6	25.293	405.2	0.421	0.425	0.423

NOTE - GAMMA-RAY SCAN FOR 14 INCH HORIZONTAL POSITION ABOVE TRAY 5 IN QUESTION
DUE TO INTERFERENCE OF DOWNCOMER APRON AND LIQUID IN DOWNCOMER.

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TABLE V (CONT'D)
PROCESS AND FROTH DENSITIES
TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION ABOVE TRAY-4		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION		
	inches	mm	Low		High		Average		Low	High	Average
			lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³			
Run : 16533	40.90	1039	2.496	40.0	2.625	42.0	2.558	41.0	0.041	0.043	0.042
	39.00	991	2.769	44.4	2.984	47.8	2.870	46.0	0.046	0.049	0.047
Horizontal Position: inch mm	37.00	940	2.592	41.5	2.700	43.2	2.651	42.5	0.043	0.045	0.044
	35.00	889	5.466	87.6	5.641	90.4	5.552	88.9	0.091	0.094	0.092
	33.00	838	126.624	426.5	127.287	437.1	126.899	430.9	0.446	0.457	0.450
	31.00	787	149.237	788.7	149.737	796.7	149.515	793.2	0.825	0.833	0.829
	30.00	762	154.819	878.1	155.063	882.0	154.941	880.1	0.918	0.922	0.920
	29.00	737	156.295	901.8	156.661	907.6	156.475	904.7	0.943	0.949	0.946
Temperature : deg. F deg. C	28.25	718	155.363	886.8	155.596	890.6	155.479	888.7	0.927	0.931	0.929
	26.00	660	19.254	308.4	124.142	386.7	122.834	365.8	0.322	0.404	0.382
Tray 4 : 212.6 1100.4	24.00	610					-0.031	-0.5			-0.001
	22.00	559					-0.038	-0.6			-0.001
	20.00	508					-0.035	-0.6			-0.001
	18.00	457	0.038	0.6	0.115	1.8	0.072	1.2	0.000	0.001	0.001
Density : lb/ft ³ kg/m ³	16.00	406	-0.044	-0.7	0.006	0.1	-0.009	-0.1	-0.001	-0.001	-0.001
	14.00	356	0.219	3.5	0.319	5.1	0.274	4.4	0.003	0.005	0.004
Liquid : 59.70 956	12.00	305	0.196	3.1	0.315	5.1	0.258	4.1	0.003	0.005	0.004
Vapor : 0.0377 10.605	10.00	254					-0.029	-0.5			-0.001
	8.00	203	-0.038	-0.6	0.027	0.4	0.014	0.2	-0.001	-0.000	-0.000
	6.00	152	0.196	3.1	0.240	3.8	0.218	3.5	0.003	0.003	0.003
	4.00	102	1.236	19.8	1.325	21.2	1.272	20.4	0.020	0.022	0.021
	3.00	76	2.365	37.9	2.565	41.1	2.445	39.2	0.039	0.042	0.040
	2.00	51	5.801	92.9	6.332	101.4	6.088	97.5	0.097	0.105	0.101
	1.25	32	10.262	164.4	10.585	169.5	10.370	166.1	0.171	0.177	0.173
Run : 16536	40.90	1039	0.082	0.0	0.038	0.6	0.015	0.2	-0.001	-0.000	-0.000
	39.00	991	0.056	0.9	0.090	1.4	0.071	1.1	0.000	0.001	0.001
Horizontal Position: inch mm	37.00	940	0.135	2.2	0.158	2.5	0.142	2.3	0.002	0.002	0.002
	35.00	889	0.544	8.7	0.590	9.5	0.565	9.0	0.008	0.009	0.009
	33.00	838	2.538	40.7	2.798	44.8	2.674	42.8	0.042	0.046	0.044
	31.00	787	10.346	165.7	10.829	173.5	10.613	170.0	0.173	0.181	0.177
	30.00	762	14.880	237.6	15.486	248.1	15.246	244.2	0.248	0.259	0.255
	29.00	737	19.687	315.4	19.912	319.0	19.804	317.2	0.329	0.333	0.331
Temperature : deg. F deg. C	28.25	718	22.496	360.3	22.790	365.1	22.591	361.9	0.377	0.382	0.378
	26.00	660	3.699	59.3	3.840	61.5	3.797	60.8	0.061	0.064	0.063
Tray 4 : 213.8 1101.0	24.00	610					-0.010	-0.2			-0.001
	22.00	559					-0.027	-0.4			-0.001
	20.00	508					-0.029	-0.5			-0.001
	18.00	457					-0.012	-0.2			-0.001
Density : lb/ft ³ kg/m ³	16.00	406					-0.029	-0.5			-0.001
	14.00	356	-0.021	-0.3	0.000	0.0	-0.011	-0.2	-0.001	-0.001	-0.001
Liquid : 59.67 956	12.00	305					-0.023	-0.4			-0.001
Vapor : 0.0386 10.619	10.00	254					-0.031	-0.5			-0.001
	8.00	203	0.521	8.3	0.579	9.3	0.545	8.7	0.008	0.009	0.008
	6.00	152	3.247	52.0	3.574	57.3	3.392	54.3	0.054	0.059	0.056
	4.00	102	11.386	182.4	11.815	189.3	11.535	184.8	0.190	0.197	0.193
	3.00	76	15.851	253.9	16.349	261.9	16.131	258.4	0.265	0.274	0.270
	2.00	51	20.519	328.7	21.092	337.9	20.923	335.2	0.343	0.353	0.350
	1.25	32	23.955	383.7	24.242	388.3	24.102	386.1	0.401	0.406	0.404
Run : 16536	40.90	1039	-0.015	-0.2	0.035	0.6	0.008	0.1	-0.001	-0.000	-0.001
	39.00	991	0.080	0.0	0.023	0.4	0.010	0.2	-0.001	-0.000	-0.000
Horizontal Position: inch mm	37.00	940	0.075	1.2	0.125	2.0	0.090	1.4	0.001	0.001	0.001
	35.00	889	0.729	11.7	0.779	12.5	0.753	12.1	0.012	0.012	0.012
	33.00	838	4.580	73.4	5.057	81.0	4.830	77.4	0.076	0.084	0.080
	31.00	787	13.369	214.1	13.782	220.8	13.534	216.8	0.224	0.230	0.226
	30.00	762	16.134	258.4	16.482	264.0	16.324	261.5	0.270	0.276	0.273
	29.00	737	19.066	305.4	19.554	313.2	19.324	309.5	0.319	0.327	0.323
Temperature : deg. F deg. C	28.25	718	21.759	348.6	21.896	350.7	21.824	349.6	0.364	0.367	0.365
	26.00	660	1.657	26.5	1.754	28.1	1.712	27.4	0.027	0.029	0.028
Tray 4 : 213.6 1100.9	24.00	610	-0.831	-0.5	0.002	0.0	-0.014	-0.2	-0.001	-0.001	-0.001
	22.00	559	-0.819	-0.3	0.002	0.0	-0.008	-0.1	-0.001	-0.001	-0.001
	20.00	508	-0.829	-0.5	0.000	0.0	-0.014	-0.2	-0.001	-0.001	-0.001
	18.00	457	-0.819	-0.3	0.000	0.0	-0.010	-0.2	-0.001	-0.001	-0.001
Density : lb/ft ³ kg/m ³	16.00	406					-0.029	-0.5			-0.001
	14.00	356					-0.023	-0.4			-0.001
Liquid : 59.68 956	12.00	305	0.023	0.4	0.071	1.1	0.041	0.7	-0.000	0.001	0.000
Vapor : 0.0385 10.617	10.00	254					-0.037	-0.6			-0.001
	8.00	203	1.058	16.9	1.175	18.8	1.111	17.8	0.017	0.019	0.018
	6.00	152	5.795	92.8	6.160	98.7	6.019	96.4	0.097	0.103	0.100
	4.00	102	14.472	231.8	15.005	240.4	14.715	235.7	0.242	0.251	0.246
	3.00	76	17.214	275.7	17.631	282.4	17.460	279.7	0.288	0.295	0.292
	2.00	51	19.837	304.9	19.277	308.8	19.167	307.0	0.319	0.323	0.321
	1.25	32	20.279	324.8	20.469	327.9	20.378	326.4	0.339	0.343	0.341

NOTE - SCAN AT 26 INCH ELEVATION FOR 20 INCH HORIZONTAL POSITION
QUESTIONABLE DUE TO INTERFERENCE FROM LIQUID IN DOWNCOMER

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TABLE V (CONT'D)
PROCESS AND FROTH DENSITIES
TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION ABOVE TRAY-4		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION		
	inches	mm	Low		High		Average		Low	High	Average
			lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³			
Run : 16536	40.90	1039	-0.010	-0.2	0.013	0.2	0.005	0.1	-0.001	-0.000	-0.001
	39.00	991	0.185	3.0	0.227	3.6	0.201	3.2	0.002	0.003	0.003
Horizontal Position: inch mm	37.00	940	0.244	3.9	0.317	5.1	0.290	4.6	0.003	0.005	0.004
	35.00	889	1.959	31.4	2.096	33.6	2.040	32.7	0.032	0.034	0.034
	33.00	838	5.105	81.8	5.276	84.5	5.211	83.5	0.085	0.088	0.087
	31.00	787	12.578	201.5	12.773	204.6	12.669	202.9	0.210	0.214	0.212
	30.00	762	18.483	296.1	18.675	299.2	18.567	297.4	0.309	0.313	0.311
	29.00	737	26.962	431.9	27.203	435.7	27.113	434.3	0.451	0.455	0.454
Temperature : deg. F deg. C	28.25	718	30.256	484.7	30.381	486.7	30.304	485.4	0.507	0.509	0.508
	26.00	660	1.459	23.4	1.636	26.2	1.553	24.9	0.024	0.027	0.025
Tray 4 : 213.7 100.9	24.00	610	-0.029	-0.5	0.000	0.0	-0.014	-0.2	-0.001	-0.001	-0.001
	22.00	559					-0.027	-0.4			-0.001
	20.00	508	-0.023	-0.4	0.013	0.2	-0.003	-0.1	-0.001	-0.000	-0.001
	18.00	457	-0.010	-0.2	0.019	0.3	0.004	0.1	-0.001	-0.000	-0.001
Density : lb/ft ³ kg/m ³	16.00	406	-0.035	-0.6	0.000	0.0	-0.035	-0.6	-0.001	-0.000	-0.001
	14.00	356	0.002	0.0	0.038	0.6	0.022	0.4	-0.001	-0.000	-0.000
Liquid Vapor : 59.68 956 : 0.0385 10.617	12.00	305	0.029	0.5	0.090	1.4	0.046	0.7	-0.000	0.001	0.000
	10.00	254					-0.029	-0.5			-0.001
	8.00	203	0.321	5.1	0.363	5.8	0.343	5.5	0.005	0.005	0.005
	6.00	152	2.186	35.0	2.498	40.0	2.326	37.3	0.036	0.041	0.038
	4.00	102	9.214	147.6	9.633	154.3	9.368	150.1	0.154	0.161	0.156
	3.00	76	12.871	206.2	13.746	220.2	13.489	216.1	0.215	0.230	0.226
	2.00	51	17.364	278.1	17.783	284.9	17.554	281.2	0.291	0.298	0.294
	1.25	32	20.787	333.0	20.979	336.0	20.898	334.8	0.348	0.351	0.350
Run : 16536	40.90	1039	1.206	19.3	1.292	20.7	1.247	20.0	0.020	0.021	0.020
	39.00	991	1.611	25.8	1.738	27.8	1.666	26.7	0.026	0.028	0.027
Horizontal Position: inch mm	37.00	940	1.579	25.3	1.680	26.9	1.619	25.9	0.026	0.028	0.026
	35.00	889	4.903	78.5	5.066	81.2	4.996	80.0	0.082	0.084	0.083
	33.00	838	12.991	448.4	12.813	451.5	12.888	449.9	0.469	0.472	0.470
	31.00	787	150.679	811.8	152.060	833.9	151.273	821.3	0.849	0.872	0.859
	30.00	762	155.165	883.7	155.494	892.1	155.455	888.3	0.924	0.933	0.929
	29.00	737	156.540	905.7	157.307	918.0	156.787	909.6	0.947	0.960	0.952
Temperature : deg. F deg. C	28.25	718	155.340	886.5	155.672	891.8	155.536	889.6	0.927	0.933	0.931
	26.00	660	122.177	355.2	123.207	371.7	122.603	362.1	0.371	0.388	0.378
Tray 4 : 213.7 100.9	24.00	610					-0.025	-0.4			-0.001
	22.00	559					-0.027	-0.4			-0.001
	20.00	508					-0.029	-0.5			-0.001
	18.00	457	0.013	0.2	0.067	1.1	0.041	0.7	-0.000	0.000	0.000
Density : lb/ft ³ kg/m ³	16.00	406					-0.031	-0.5			-0.001
	14.00	356	0.152	2.4	0.254	4.1	0.207	3.3	0.002	0.004	0.003
Liquid Vapor : 59.68 956 : 0.0385 10.617	12.00	305	0.154	2.5	0.223	3.6	0.191	3.1	0.002	0.003	0.003
	10.00	254					-0.038	-0.6			-0.001
	8.00	203	-0.031	-0.5	0.004	0.1	-0.008	-0.1	-0.001	-0.001	-0.001
	6.00	152	0.008	0.1	0.098	1.6	0.059	0.9	-0.001	0.001	0.000
	4.00	102	0.554	8.9	0.690	11.1	0.617	9.9	0.009	0.011	0.010
	3.00	76	1.131	18.1	1.300	20.8	1.219	19.5	0.018	0.021	0.020
	2.00	51	3.711	59.4	3.851	61.7	3.793	60.8	0.062	0.064	0.063
	1.25	32	7.193	115.2	7.349	117.7	7.268	116.4	0.120	0.123	0.121
Run : 16537	40.90	1039	-0.004	-0.1	0.013	0.2	0.006	0.1	-0.001	-0.000	-0.001
	39.00	991	0.119	1.9	0.162	2.6	0.138	2.2	0.001	0.002	0.002
Horizontal Position: inch mm	37.00	940	0.206	3.3	0.258	4.1	0.229	3.7	0.003	0.004	0.003
	35.00	889	1.415	22.7	1.496	24.0	1.461	23.4	0.023	0.024	0.024
	33.00	838	2.957	47.4	3.036	48.6	3.008	48.2	0.049	0.050	0.050
	31.00	787	8.281	132.7	8.497	136.1	8.336	133.5	0.138	0.142	0.139
	30.00	762	12.878	206.3	13.111	210.0	12.972	207.8	0.215	0.219	0.217
	29.00	737	20.942	335.5	21.112	338.2	21.031	336.9	0.350	0.353	0.352
Temperature : deg. F deg. C	28.25	718									
	26.00	660	1.748	28.0	1.896	30.4	1.824	29.2	0.029	0.031	0.030
Tray 4 : 213.3 100.7	24.00	610	-0.013	-0.2	0.006	0.1	-0.001	-0.0	-0.001	-0.001	-0.001
	22.00	559					-0.019	-0.3			-0.001
	20.00	508					-0.021	-0.3			-0.001
	18.00	457					-0.033	-0.5			-0.001
Density : lb/ft ³ kg/m ³	16.00	406					-0.021	-0.3			-0.001
	14.00	356					-0.025	-0.4			-0.001
Liquid Vapor : 59.69 956 : 0.0382 10.613	12.00	305	0.008	0.1	0.046	0.7	0.028	0.5	-0.001	0.000	-0.000
	10.00	254					-0.035	-0.6			-0.001
	8.00	203	0.083	1.3	0.125	2.0	0.102	1.6	0.001	0.001	0.001
	6.00	152	0.715	11.5	0.779	12.5	0.750	12.0	0.011	0.012	0.012
	4.00	102	3.890	62.3	4.207	67.4	4.035	64.6	0.065	0.070	0.067
	3.00	76	7.720	123.7	8.016	128.4	7.921	126.9	0.129	0.134	0.132
	2.00	51	12.261	196.4	12.634	202.4	12.409	198.8	0.205	0.211	0.207
	1.25	32	16.841	269.8	17.108	274.1	17.015	272.6	0.282	0.286	0.285

NOTE - GAMMA-RAY SCAN FOR 14 INCH HORIZONTAL POSITION ABOVE TRAY 5 IN QUESTION DUE TO INTERFERENCE OF DOWNCOMER APRON AND LIQUID IN DOWNCOMER.

SCAN AT 26 INCH ELEVATION FOR 20 INCH HORIZONTAL POSITION QUESTIONABLE DUE TO INTERFERENCE FROM LIQUID IN DOWNCOMER

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PROCESS AND FROTH DENSITIES
TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION ABOVE TRAY-4		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION		
	inches	mm	Low		High		Average		Low	High	Average
			lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³			
Run : 16537	40.90	1039	0.329	5.3	0.540	8.7	0.441	7.1	0.005	0.008	0.007
	39.00	991	1.025	16.4	1.127	18.0	1.082	17.3	0.017	0.018	0.017
Horizontal Position: inch mm	37.00	940	1.498	24.0	1.721	27.6	1.613	25.8	0.024	0.028	0.026
	35.00	889	3.686	59.0	3.844	61.6	3.772	60.4	0.061	0.064	0.063
	33.00	838	11.852	189.8	12.417	198.9	12.269	196.5	0.198	0.208	0.205
	31.00	787	38.122	610.7	39.420	631.4	38.567	617.8	0.638	0.660	0.646
	30.00	762	147.682	763.8	147.993	768.8	147.824	766.1	0.799	0.804	0.801
	29.00	737	152.811	846.0	153.609	858.7	153.094	850.5	0.885	0.898	0.889
Temperature : deg. F/deg. C	28.25	718	158.475	856.6	153.956	864.3	153.693	860.1	0.896	0.904	0.899
	26.00	660	21.256	340.5	125.474	408.1	123.957	383.8	0.356	0.426	0.401
Tray 4 : 213.0 100.6	24.00	610	-0.027	-0.4	0.002	0.0	-0.008	-0.1	-0.001	-0.001	-0.001
	22.00	559					-0.025	-0.4			-0.001
	20.00	508	-0.019	-0.3	0.015	0.2	0.000	0.0	-0.001	-0.000	-0.001
	18.00	457	0.000		0.077	1.2	0.033	0.5	-0.001	0.001	-0.000
Density : lb/ft ³ kg/m ³	16.00	406	-0.023	-0.4	0.029	0.5	0.003	0.0	-0.001	-0.000	-0.001
	14.00	356	0.229	3.7	0.283	4.5	0.254	4.1	0.003	0.004	0.004
Liquid : 59.69 956	12.00	305	0.188	3.0	0.248	4.0	0.219	3.5	0.003	0.004	0.003
Vapor : 0.0380 0.609	10.00	254	-0.033	-0.5	0.000	0.0	-0.016	-0.3	-0.001	-0.001	-0.001
	8.00	203					-0.040	-0.6			-0.001
	6.00	152	-0.008	-0.1	0.033	0.5	0.003	0.0	-0.001	-0.000	-0.001
	4.00	102	0.252	4.0	0.329	5.3	0.283	4.5	0.004	0.005	0.004
	3.00	76	0.435	7.0	0.552	8.8	0.503	8.1	0.007	0.009	0.008
	2.00	51	2.198	35.2	2.350	37.6	2.263	36.3	0.036	0.039	0.037
	1.25	32	4.570	73.2	4.670	74.8	4.619	74.0	0.076	0.078	0.077
Run : 16552	40.90	1039	0.268	4.3	0.357	5.7	0.295	4.7	0.004	0.005	0.004
	39.00	991	0.500	8.0	0.693	11.1	0.634	10.2	0.008	0.011	0.010
Horizontal Position: inch mm	37.00	940	1.438	23.0	1.669	26.7	1.552	24.9	0.023	0.027	0.025
	35.00	889	3.749	60.1	4.267	68.4	4.018	64.4	0.062	0.071	0.067
	33.00	838	10.810	173.2	11.460	183.6	11.025	176.6	0.181	0.192	0.184
	31.00	787	19.070	305.5	19.670	315.1	19.249	308.3	0.319	0.329	0.322
	30.00	762	121.270	340.7	121.960	351.8	121.691	347.5	0.356	0.368	0.363
	29.00	737	123.280	372.9	123.740	380.3	123.555	377.3	0.390	0.397	0.394
Temperature : deg. F/deg. C	28.25	718	24.73	396.1	25	400.5	24.789	397.1	0.414	0.419	0.415
	26.00	660	10.2088	3.3	10.2622	4.2	10.2305	3.7	0.003	0.004	0.003
Tray 4 : 213.9 101.0	24.00	610	-1.471	-23.6	-1.414	-22.7	-1.443	-23.1	-0.025	-0.024	-0.025
	22.00	559	10.0488	0.8	10.0799	1.3	10.0596	1.0	0.000	0.001	0.000
	20.00	508	10.0054	0.1	10.0320	0.5	10.0223	0.4	-0.001	-0.000	-0.000
Density : lb/ft ³ kg/m ³	18.00	457	10.0229	0.4	10.0474	0.8	10.0361	0.6	-0.000	0.000	-0.000
	16.00	406	10.0370	0.6	10.0614	1.0	10.0477	0.8	-0.000	0.000	0.000
	14.00	356	10.0107	0.2	10.0409	0.7	10.0276	0.4	-0.000	0.000	-0.000
Liquid : 59.67 956	12.00	305	10.1733	2.8	10.1997	3.2	10.1865	3.0	0.002	0.003	0.002
Vapor : 0.0386 0.619	10.00	254	10.6316	10.1	10.8167	13.1	10.7149	11.5	0.010	0.013	0.011
	8.00	203	4.235	67.8	4.858	77.8	4.5380	72.7	0.070	0.081	0.075
	6.00	152	12.59	201.7	13.47	215.8	13.110	210.0	0.210	0.225	0.219
	4.00	102	21.13	338.5	21.56	345.4	21.384	342.5	0.354	0.361	0.358
	3.00	76	25.31	405.4	26.06	417.4	25.659	411.0	0.424	0.436	0.430
	2.00	51	28.96	463.9	29.13	466.6	29.041	465.2	0.485	0.488	0.486
	1.25	32	29.54	473.2	29.79	477.2	29.625	474.6	0.495	0.499	0.496
Run : 16552	40.90	1039	10.2119	3.4	10.2479	4.0	10.2283	3.7	0.003	0.004	0.003
	39.00	991	10.4617	7.4	10.5188	8.3	10.4828	7.7	0.007	0.008	0.007
Horizontal Position: inch mm	37.00	940	1.137	18.2	1.313	21.0	1.2132	19.4	0.018	0.021	0.020
	35.00	889	4.311	69.1	4.559	73.0	4.4659	71.5	0.072	0.076	0.074
	33.00	838	12.59	201.7	13.45	215.4	13.037	208.8	0.210	0.225	0.218
	31.00	787	19.94	319.4	21.23	340.1	20.660	331.0	0.334	0.355	0.346
	30.00	762	23.43	375.3	23.75	380.4	23.534	377.0	0.392	0.398	0.394
	29.00	737	24.72	396.0	25.43	407.3	25.084	401.8	0.414	0.426	0.420
Temperature : deg. F/deg. C	28.25	718	25.21	403.8	25.48	408.2	25.385	406.6	0.422	0.427	0.425
	26.00	660	1.579	25.3	1.692	27.1	1.6275	26.1	0.026	0.028	0.027
Tray 4 : 213.8 101.0	24.00	610	-1.477	-23.7	-1.413	-22.6	-1.438	-23.0	-0.025	-0.024	-0.025
	22.00	559	10.0712	1.1	10.0822	1.3	10.0787	1.3	0.001	0.001	0.001
	20.00	508	10.0153	0.2	10.0379	0.6	10.0244	0.4	-0.000	-0.000	-0.000
Density : lb/ft ³ kg/m ³	18.00	457	10.0380	0.6	10.0563	0.9	10.0461	0.7	-0.000	0.000	0.000
	16.00	406	10.0245	0.4	10.0466	0.7	10.0338	0.5	-0.000	0.000	-0.000
	14.00	356	10.0615	1.0	10.0793	1.3	10.0711	1.1	0.000	0.001	0.001
Liquid : 59.67 956	12.00	305	10.2341	3.7	10.2577	4.1	10.2423	3.9	0.003	0.004	0.003
Vapor : 0.0386 0.619	10.00	254	10.4706	7.5	10.5642	9.0	10.5235	8.4	0.007	0.009	0.008
	8.00	203	2.875	46.1	2.875	46.1	2.875	46.1	0.048	0.048	0.048
	6.00	152	12.77	204.6	13.74	220.1	13.17	211.0	0.213	0.230	0.220
	4.00	102	21.01	336.5	21.77	348.7	21.377	342.4	0.352	0.364	0.358
	3.00	76	22.94	367.5	23.66	379.0	23.274	372.8	0.384	0.396	0.390
	2.00	51	22.91	367.0	23.18	371.3	23.082	369.7	0.384	0.388	0.386
	1.25	32	22.52	360.7	22.69	363.5	22.584	361.8	0.377	0.380	0.378

NOTE - SCAN AT 26 INCH ELEVATION FOR 20 INCH HORIZONTAL POSITION
QUESTIONABLE DUE TO INTERFERENCE FROM LIQUID IN DOWNCOMER

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TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION ABOVE TRAY-4		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION		
	inches	mm	Low		High		Average		Low	High	Average
			lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³			
Run : 16552	40.90	1039	0.88	14.1	0.9092	14.6	0.8911	14.3	0.014	0.015	0.014
	39.00	991	1.07	17.1	1.118	17.9	1.0879	17.4	0.017	0.018	0.018
Horizontal Position: inch mm	37.00	940	1.32	21.1	1.387	22.2	1.3508	21.6	0.021	0.023	0.022
	35.00	889	4.132	66.2	4.195	67.2	4.1657	66.7	0.069	0.070	0.069
	33.00	838	8.401	134.6	8.558	137.1	8.4919	136.0	0.140	0.143	0.142
	31.00	787	18	288.3	18.35	293.9	18.181	291.2	0.301	0.307	0.304
	30.00	762	26.29	421.1	26.44	423.5	26.381	422.6	0.440	0.443	0.442
	29.00	737	35.3	565.5	35.46	568.0	35.402	567.1	0.591	0.594	0.593
Temperature : deg. F deg. C	28.25	718	36.32	581.8	36.46	584.0	36.400	583.1	0.608	0.611	0.610
	26.00	660	0.7551	12.1	1.05	16.8	0.9650	15.5	0.012	0.017	0.016
Tray 4 : 213.9 101.0	24.00	610									
	22.00	559	-0.365	-5.8	-0.333	-5.3	-0.351	-5.6	-0.007	-0.006	-0.007
	20.00	508	0.0370	0.6	0.0625	1.0	0.0497	0.8	-0.000	0.000	0.000
	18.00	457	0.1929	3.1	0.2353	3.8	0.2057	3.3	0.003	0.003	0.003
Density : lb/ft ³ kg/m ³	16.00	406	-0.110	-1.8	0.0996	1.6	0.0378	0.6	-0.003	0.001	-0.000
	14.00	356	0.1338	2.1	0.1621	2.6	0.1495	2.4	0.002	0.002	0.002
Liquid : 59.67 956	12.00	305	0.2163	3.5	0.2323	3.7	0.2231	3.6	0.003	0.003	0.003
Vapor : 0.0386 0.620	10.00	254	-0.242	-3.9	-0.164	-2.6	-0.193	-3.1	-0.005	-0.003	-0.004
	8.00	203	2.779	44.5	3.213	51.5	3.0446	48.8	0.046	0.053	0.050
	6.00	152	11.5	184.2	12.23	195.9	11.851	189.8	0.192	0.204	0.198
	4.00	102	20.9	334.8	21.3	341.2	21.127	338.4	0.350	0.357	0.354
	3.00	76	23.88	382.5	24.31	389.4	24.071	385.6	0.400	0.407	0.403
	2.00	51	26.46	423.8	26.67	427.2	26.550	425.3	0.443	0.447	0.445
	1.25	32	26.95	431.7	27.14	434.7	27.022	432.9	0.451	0.454	0.453
Run : 16552	40.90	1039									
	39.00	991									
Horizontal Position: inch mm	37.00	940	6.536	104.7	6.643	106.4	6.5808	105.4	0.109	0.111	0.110
	35.00	889	14.37	230.2	15.6	249.9	15.046	241.0	0.240	0.261	0.252
	33.00	838	38.05	609.5	40.48	648.4	39.432	631.7	0.637	0.678	0.661
	31.00	787	54.93	879.9	56.33	902.3	55.455	888.3	0.921	0.944	0.929
	30.00	762	56.73	908.7	57.13	915.1	56.91	911.6	0.951	0.957	0.954
	29.00	737	57.32	918.2	57.66	923.6	57.495	921.0	0.961	0.966	0.964
Temperature : deg. F deg. C	28.25	718	55.53	889.5	55.92	895.8	55.708	892.4	0.931	0.937	0.934
	26.00	660	19.91	318.9	22.49	360.3	21.352	342.0	0.333	0.377	0.357
Tray 4 : 213.9 101.1	24.00	610									
	22.00	559	0.0344	0.6	0.0963	1.5	0.0670	1.1	-0.000	0.001	0.000
	20.00	508	0.3849	6.2	0.5239	8.4	0.4632	7.4	0.006	0.008	0.007
	18.00	457	0.6218	10.0	0.6965	11.2	0.6531	10.5	0.010	0.011	0.010
Density : lb/ft ³ kg/m ³	16.00	406	0.5288	8.5	0.5811	9.3	0.5476	8.8	0.008	0.009	0.009
	14.00	356	0.7738	12.4	0.8644	13.8	0.8177	13.1	0.012	0.014	0.013
Liquid : 59.67 956	12.00	305	0.668	10.7	0.7403	11.9	0.7100	11.4	0.011	0.012	0.011
Vapor : 0.0387 0.620	10.00	254	0.0029	0.0	0.0631	1.0	0.0391	0.6	-0.001	0.000	0.000
	8.00	203	0.9952	15.9	1.076	17.2	1.0428	16.7	0.016	0.017	0.017
	6.00	152	2.768	44.3	3.117	49.9	2.9341	47.0	0.046	0.052	0.049
	4.00	102	8.068	129.2	8.44	135.2	8.2250	131.8	0.135	0.141	0.137
	3.00	76	11.65	186.6	12.43	199.1	11.965	191.7	0.195	0.208	0.200
	2.00	51	17.17	275.0	18.29	293.0	17.637	282.5	0.287	0.306	0.295
	1.25	32	21.48	344.1	21.79	349.0	21.631	346.5	0.360	0.365	0.362
Run : 16554	40.90	1039	0.1701	2.7	0.1833	2.9	0.1763	2.8	0.002	0.002	0.002
	39.00	991	0.3368	5.4	0.3552	5.7	0.3497	5.6	0.005	0.005	0.005
Horizontal Position: inch mm	37.00	940	0.6956	11.1	0.7206	11.5	0.7074	11.3	0.011	0.011	0.011
	35.00	889	1.485	23.8	1.619	25.9	1.542	24.7	0.024	0.027	0.025
	33.00	838	4.156	66.6	4.413	70.7	4.2778	68.5	0.069	0.073	0.071
	31.00	787	11.98	191.9	12.46	199.6	12.239	196.1	0.200	0.208	0.205
	30.00	762	16.42	263.0	16.8	269.1	16.598	265.9	0.275	0.281	0.278
	29.00	737	20.87	334.3	21	336.4	20.929	335.3	0.349	0.352	0.350
Temperature : deg. F deg. C	28.25	718	22.6	362.0	22.71	363.8	22.657	362.9	0.378	0.380	0.379
	26.00	660	-0.331	-5.3	-0.215	-3.4	-0.269	-4.3	-0.006	-0.004	-0.005
Tray 4 : 213.8 101.0	24.00	610	-1.71	-27.4	-1.63	-26.1	-1.680	-26.9	-0.029	-0.028	-0.029
	22.00	559	-0.145	-2.3	-0.108	-1.7	-0.123	-2.0	-0.003	-0.002	-0.003
	20.00	508	0.0031	0.1	0.0235	0.4	0.0123	0.2	-0.001	-0.000	-0.000
	18.00	457	0.0002	0.0	0.0094	0.2	0.0029	0.0	-0.001	-0.000	-0.001
Density : lb/ft ³ kg/m ³	16.00	406	0.0534	0.9	0.0729	1.2	0.0668	1.1	0.000	0.001	0.000
	14.00	356	0.0046	0.1	0.0200	0.3	0.0114	0.2	-0.001	-0.000	-0.000
Liquid : 59.67 956	12.00	305	0.0133	0.2	0.0360	0.6	0.0228	0.4	-0.000	-0.000	-0.000
Vapor : 0.0386 0.618	10.00	254	-0.233	-3.7	-0.203	-3.3	-0.215	-3.5	-0.005	-0.004	-0.004
	8.00	203	0.5873	9.4	0.6153	9.9	0.6001	9.6	0.009	0.010	0.009
	6.00	152	3.523	56.4	3.839	61.5	3.6220	58.0	0.058	0.064	0.060
	4.00	102	11.82	189.3	12.24	196.1	12.010	192.4	0.198	0.205	0.201
	3.00	76	16.58	265.6	17.28	276.8	16.952	271.6	0.277	0.289	0.284
	2.00	51	21.21	339.8	21.7	347.6	21.569	345.5	0.355	0.363	0.361
	1.25	32	24.37	390.4	24.49	392.3	24.416	391.1	0.408	0.410	0.409

NOTE - GAMMA-RAY SCAN FOR 14 INCH HORIZONTAL POSITION ABOVE TRAY 5 IN QUESTION DUE TO INTERFERENCE OF DOWNCOMER APRON AND LIQUID IN DOWNCOMER.

SCAN AT 26 INCH ELEVATION FOR 20 INCH HORIZONTAL POSITION QUESTIONABLE DUE TO INTERFERENCE FROM LIQUID IN DOWNCOMER

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TABLE V (CONT'D)
PROCESS AND FROTH DENSITIES
TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION ABOVE TRAY-4		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION		
			Low		High		Average		Low	High	Average
	inches	mm	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³			
Run : 16554	40.90	1039	10.0895	1.4	10.1124	1.8	10.1020	1.6	0.001	0.001	0.001
	39.00	991	10.2509	4.0	10.2945	4.7	10.2749	4.4	0.004	0.004	0.004
Horizontal inch mm	37.00	940	10.6795	10.9	10.7438	11.9	10.7134	11.4	0.011	0.012	0.011
Position:-----	35.00	889	1.848	29.6	2.017	32.3	11.9500	31.2	0.030	0.033	0.032
	33.00	838	6.094	97.6	6.347	101.7	16.2266	99.7	0.102	0.106	0.104
	31.00	787	15.5	248.3	15.79	252.9	115.654	250.8	0.259	0.264	0.262
	30.00	762	19.02	304.7	19.38	310.4	119.261	308.5	0.318	0.324	0.322
	29.00	737	22.94	367.5	23.2	371.6	123.096	370.0	0.384	0.388	0.387
Temperature : deg. F deg. C	28.25	718	24.38	390.5	24.55	393.3	124.488	392.3	0.408	0.411	0.410
	26.00	660	1.633	26.2	1.686	27.0	11.6608	26.6	0.027	0.028	0.027
Tray 4 : 213.8 101.0	24.00	610	-1.385	-22.2	-1.348	-21.6	-1.366	-21.9	-0.024	-0.023	-0.024
	22.00	559	-0.175	-2.8	-0.141	-2.3	-0.156	-2.5	-0.004	-0.003	-0.003
	20.00	508	10.0132	0.2	10.0444	0.7	10.0321	0.5	-0.000	0.000	-0.000
	18.00	457	10.0016	0.0	10.0088	0.1	10.0048	0.1	-0.001	-0.000	-0.001
Density : lb/ft ³ kg/m ³	16.00	406	10.0005	0.0	10.0217	0.3	10.0117	0.2	-0.001	-0.000	-0.000
	14.00	356	10.0002	0.0	10.0186	0.3	10.0074	0.1	-0.001	-0.000	-0.001
Liquid : 59.67 956	12.00	305	10.0496	0.8	10.0753	1.2	10.0649	1.0	0.000	0.001	0.000
Vapor : 0.0386 0.618	10.00	254	-0.205	-3.3	-0.162	-2.6	-0.184	-3.0	-0.004	-0.003	-0.004
	8.00	203	1.013	16.2	1.078	17.3	11.0422	16.7	0.016	0.017	0.017
	6.00	152	5.363	85.9	5.85	93.7	15.6124	89.9	0.089	0.097	0.093
	4.00	102	15.09	241.7	15.55	249.1	15.276	244.7	0.252	0.260	0.256
	3.00	76	18	288.3	18.45	295.5	18.23	292.0	0.301	0.309	0.305
	2.00	51	18.9	302.7	19.44	311.4	19.189	307.4	0.316	0.325	0.321
	1.25	32	20.04	321.0	20.16	322.9	20.106	322.1	0.335	0.337	0.337
Run : 16554	40.90	1039	12.7	10.8433	13.5	10.8159	13.1	0.013	0.013	0.013	
	39.00	991	0.79	12.7	0.8433	13.5	10.8159	13.1	0.013	0.013	0.013
Horizontal inch mm	37.00	940	0.9534	15.3	0.99	15.9	10.9727	15.6	0.015	0.016	0.016
Position:-----	35.00	889	3.543	56.8	3.59	57.5	3.565	57.1	0.059	0.060	0.059
	33.00	838	8.034	128.7	8.091	129.6	18.0659	129.2	0.134	0.135	0.135
	31.00	787	17.64	282.6	17.96	287.7	17.778	284.8	0.295	0.301	0.297
	30.00	762	24.76	396.6	24.99	400.3	124.848	398.0	0.415	0.418	0.416
	29.00	737	33	528.6	33.19	531.7	33.07	529.7	0.553	0.556	0.554
Temperatures: deg. F deg. C	28.25	718	33.94	543.7	34.19	547.7	134.074	545.8	0.569	0.573	0.571
	26.00	660	1.668	26.7	1.739	27.9	11.7004	27.2	0.027	0.029	0.028
Tray 4 : 213.8 101.0	24.00	610									
	22.00	559	-0.211	-3.4	-0.179	-2.9	-0.196	-3.1	-0.004	-0.004	-0.004
	20.00	508	10.0092	0.1	10.0246	0.4	10.0155	0.2	-0.000	-0.000	-0.000
	18.00	457	10.0670	1.1	10.1007	1.6	10.0840	1.3	0.000	0.001	0.001
Density : lb/ft ³ kg/m ³	16.00	406	10.0340	0.5	10.0516	0.8	10.0441	0.7	-0.000	0.000	0.000
	14.00	356	10.0758	1.2	10.1153	1.8	10.0963	1.5	0.001	0.001	0.001
Liquid : 59.67 956	12.00	305	10.0743	1.2	10.104	1.7	10.0890	1.4	0.001	0.001	0.001
Vapor : 0.0386 0.619	10.00	254	-0.473	-7.6	-0.456	-7.3	-0.465	-7.5	-0.009	-0.008	-0.008
	8.00	203	10.4388	7.0	10.4719	7.6	10.4532	7.3	0.007	0.007	0.007
	6.00	152	2.482	39.8	2.73	43.7	12.6144	41.9	0.041	0.045	0.043
	4.00	102	10.28	164.7	10.68	171.1	10.444	167.3	0.172	0.178	0.174
	3.00	76	14.3	229.1	14.77	236.6	14.605	234.0	0.239	0.247	0.244
	2.00	51	18.74	300.2	18.93	303.2	18.839	301.8	0.314	0.317	0.315
	1.25	32	21.48	344.1	21.64	346.6	21.581	345.7	0.360	0.362	0.361
Run : 16554	40.90	1039	1.661	26.6	1.843	29.5	11.7674	28.3	0.027	0.030	0.029
	39.00	991	1.794	28.7	1.925	30.8	11.8549	29.7	0.029	0.032	0.030
Horizontal inch mm	37.00	940	2.359	37.8	2.563	41.1	12.4612	39.4	0.039	0.042	0.041
Position:-----	35.00	889	7.829	125.4	8.561	137.1	18.0875	129.6	0.131	0.143	0.135
	33.00	838	30.75	492.6	31.55	505.4	131.040	497.2	0.515	0.528	0.520
	31.00	787	50.17	803.6	51.17	819.7	150.709	812.3	0.841	0.857	0.850
	30.00	762	55.16	883.6	55.65	891.4	155.424	887.8	0.924	0.933	0.929
	29.00	737	56.01	897.2	56.38	903.1	156.172	899.8	0.939	0.945	0.941
Temperature : deg. F deg. C	28.25	718	54.49	872.8	55.01	881.2	154.735	876.8	0.913	0.922	0.917
	26.00	660	22.07	353.5	23.95	383.6	123.482	376.2	0.369	0.401	0.393
Tray 4 : 213.9 101.0	24.00	610									
	22.00	559	-0.594	-9.5	-0.412	-6.6	-0.511	-8.2	-0.011	-0.008	-0.009
	20.00	508	10.0205	0.3	10.0673	1.1	10.0445	0.7	-0.000	0.000	0.000
	18.00	457	10.0604	1.0	10.1379	2.2	10.1106	1.8	0.000	0.002	0.001
Density : lb/ft ³ kg/m ³	16.00	406	10.0014	0.0	10.0466	0.7	10.0169	0.3	-0.001	0.000	-0.000
	14.00	356	0.234	3.7	10.2928	4.7	10.2600	4.2	0.003	0.004	0.004
Liquid : 59.67 956	12.00	305	10.1081	1.7	10.2053	3.3	10.1627	2.6	0.001	0.003	0.002
Vapor : 0.0386 0.619	10.00	254	-0.746	-12.0	-0.678	-10.9	-0.707	-11.3	-0.013	-0.012	-0.013
	8.00	203	10.0042	0.1	10.0641	1.0	10.0342	0.5	-0.001	0.000	-0.000
	6.00	152	10.2001	3.2	10.2969	4.8	10.2532	4.1	0.003	0.004	0.004
	4.00	102	10.9943	15.9	1.083	17.3	11.0493	16.8	0.016	0.018	0.017
	3.00	76	1.707	27.3	1.814	29.1	11.7498	28.0	0.028	0.030	0.029
	2.00	51	4.31	69.0	4.448	71.3	14.3969	70.4	0.072	0.074	0.073
	1.25	32	7.239	116.0	7.535	120.7	17.3873	118.3	0.121	0.126	0.123

NOTE - GAMMA-RAY SCAN FOR 14 INCH HORIZONTAL POSITION ABOVE TRAY 5 IN QUESTION DUE TO INTERFERENCE OF DOWNCOMER APRON AND LIQUID IN DOWNCOMER.

SCAN AT 26 INCH ELEVATION FOR 20 INCH HORIZONTAL POSITION QUESTIONABLE DUE TO INTERFERENCE FROM LIQUID IN DOWNCOMER

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PROCESS AND FROTH DENSITIES
TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION ABOVE TRAY-4		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION			
	inches	mm	Low		High		Average		Low	High	Average	
			lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³				
Run : 16557	40.90	1039										
	39.00	991										
Horizontal Position: 0 0	37.00	940	1.426	22.8	1.59	25.5	11.5443	24.7	0.023	0.026	0.025	
	35.00	889	2.953	47.3	3.776	60.5	13.3589	53.8	0.049	0.063	0.056	
	33.00	838	6.735	107.9	7.496	120.1	17.0030	112.2	0.112	0.125	0.117	
	31.00	787	11.42	182.9	12.15	194.6	11.737	188.0	0.191	0.203	0.196	
	30.00	762	13.47	215.8	13.94	223.3	113.694	219.4	0.226	0.233	0.229	
	29.00	737	16.78	268.8	17.59	281.8	117.108	274.0	0.281	0.295	0.287	
Temperature : deg. F deg. C	28.25	718	19.75	316.4	19.99	320.2	19.92	319.1	0.331	0.335	0.334	
	26.00	660	-0.692	-11.1	-0.565	-9.1	-0.640	-10.3	-0.012	-0.010	-0.011	
Tray 4 : 217.0 102.8	24.00	610	-1.935	-31.0	-1.889	-30.3	-1.905	-30.5	-0.033	-0.032	-0.033	
	22.00	559	-0.182	-2.9	-0.141	-2.3	-0.162	-2.6	-0.004	-0.003	-0.003	
	20.00	508	-0.805	-12.9	-0.794	-12.7	-0.799	-12.8	-0.014	-0.014	-0.014	
	18.00	457	0.0015	0.0	0.0190	0.3	0.0108	0.2	-0.001	-0.000	-0.001	
Density : lb/ft ³ kg/m ³	16.00	406	0.0350	0.6	0.0529	0.8	0.0426	0.7	-0.000	0.000	0.000	
	14.00	356	0.0633	1.0	0.1335	2.1	0.0921	1.5	0.000	0.002	0.001	
Liquid : 59.58 954	12.00	305	0.3882	6.2	0.5267	8.4	0.4600	7.4	0.006	0.008	0.007	
Vapor : 0.0409 0.656	10.00	254	0.742	11.9	1.292	20.7	1.0356	16.6	0.012	0.021	0.017	
	8.00	203	3.499	56.0	4.426	70.9	13.7855	60.6	0.058	0.074	0.063	
	6.00	152	8.573	137.3	9.152	146.6	18.8829	142.3	0.143	0.153	0.148	
	4.00	102	12.32	197.3	13.64	218.5	113.176	211.1	0.206	0.228	0.221	
	3.00	76	14.57	233.4	15.91	254.9	115.246	244.2	0.244	0.267	0.255	
	2.00	51	18.55	297.1	19.43	311.2	119.03	304.8	0.311	0.326	0.319	
	1.25	32										
Run : 16557	40.90	1039										
	39.00	991	0.8796	14.1	1.029	16.5	10.9593	15.4	0.014	0.017	0.015	
Horizontal Position: 6 152	37.00	940	2.21	35.4	3.044	48.8	12.5163	40.3	0.036	0.050	0.042	
	35.00	889	5.668	90.8	6.731	107.8	16.1450	98.4	0.095	0.112	0.103	
	33.00	838	11.26	180.4	12.74	204.1	111.991	192.1	0.188	0.213	0.201	
	31.00	787	14.96	239.6	16.24	260.1	115.522	248.7	0.251	0.272	0.260	
	30.00	762	15.95	255.5	16.62	266.2	116.285	260.9	0.267	0.278	0.273	
	29.00	737	19.29	309.0	19.78	316.8	119.457	311.7	0.323	0.332	0.326	
Temperature : deg. F deg. C	28.25	718	21.46	343.8	21.78	348.9	121.630	346.5	0.360	0.365	0.363	
	26.00	660	1.183	18.9	1.263	20.2	1.2175	19.5	0.019	0.021	0.020	
Tray 4 : 217.3 102.9	24.00	610	-1.778	-28.5	-1.741	-27.9	-1.754	-28.1	-0.031	-0.030	-0.030	
	22.00	559	-0.161	-2.6	-0.129	-2.1	-0.148	-2.4	-0.003	-0.003	-0.003	
	20.00	508	0.0022	0.0	0.0177	0.3	0.0111	0.2	-0.001	-0.000	-0.001	
	18.00	457	0.0359	0.6	0.0487	0.8	0.0422	0.7	-0.000	0.000	0.000	
Density : lb/ft ³ kg/m ³	16.00	406	0.0326	0.5	0.0523	0.8	0.0448	0.7	-0.000	0.000	0.000	
	14.00	356	0.1359	2.2	0.1679	2.7	0.1488	2.4	0.002	0.002	0.002	
Liquid : 59.58 954	12.00	305	0.3896	6.2	0.4915	7.9	0.4410	7.1	0.006	0.008	0.007	
Vapor : 0.0411 0.659	10.00	254	0.5937	9.5	0.8323	13.3	0.7272	11.6	0.009	0.013	0.012	
	8.00	203	3.522	56.4	4.204	67.3	13.9292	62.9	0.058	0.070	0.065	
	6.00	152	8.855	141.8	9.543	152.9	19.2082	147.5	0.148	0.160	0.154	
	4.00	102	12.43	199.1	13.91	222.8	113.141	210.5	0.208	0.233	0.220	
	3.00	76	13.2	211.4	13.99	224.1	113.568	217.3	0.221	0.234	0.227	
	2.00	51	13.95	223.5	15.03	240.8	114.602	233.9	0.234	0.252	0.245	
	1.25	32	16.35	261.9	17.11	274.1	116.84	269.8	0.274	0.287	0.282	
Run : 16557	40.90	1039	0.5728	9.2	0.6331	10.1	0.6030	9.7	0.009	0.010	0.009	
	39.00	991	0.8606	13.8	0.9747	15.6	0.9321	14.9	0.014	0.016	0.015	
Horizontal Position: 14 356	37.00	940	1.774	28.4	1.98	31.7	11.8566	29.7	0.029	0.033	0.030	
	35.00	889	4.892	78.4	5.142	82.4	15.0083	80.2	0.081	0.086	0.083	
	33.00	838	8.36	133.9	8.666	138.8	18.5018	136.2	0.140	0.145	0.142	
	31.00	787	16.24	260.1	16.91	270.9	116.539	264.9	0.272	0.283	0.277	
	30.00	762	22.75	364.4	23.24	372.3	122.921	367.2	0.381	0.390	0.384	
	29.00	737	30.39	486.8	30.58	489.8	130.482	488.3	0.510	0.513	0.511	
Temperatures: deg. F deg. C	28.25	718	31.93	511.5	32.11	514.4	132.027	513.0	0.536	0.539	0.537	
	26.00	660	2.534	40.6	2.707	43.4	2.627	42.1	0.042	0.045	0.043	
Tray 4 : 217.2 102.9	24.00	610										
	22.00	559	-0.236	-3.8	-0.212	-3.4	-0.222	-3.6	-0.005	-0.004	-0.004	
	20.00	508	-0.101	-1.6	0.0945	1.5	0.0201	0.3	-0.002	0.001	-0.000	
	18.00	457	0.0006	0.0	0.0167	0.3	0.0045	0.1	-0.001	-0.000	-0.001	
Density : lb/ft ³ kg/m ³	16.00	406	-0.114	-1.8	0.0980	1.6	-0.054	-0.9	-0.003	0.001	-0.002	
	14.00	356	0.0516	0.8	0.0782	1.3	0.0674	1.1	0.000	0.001	0.000	
Liquid : 59.58 954	12.00	305	0.2228	3.6	0.2495	4.0	0.2353	3.8	0.003	0.004	0.003	
Vapor : 0.0411 0.659	10.00	254	0.1319	2.1	0.3057	4.9	0.2133	3.4	0.002	0.004	0.003	
	8.00	203	2.591	41.5	3.073	49.2	12.8914	46.3	0.043	0.051	0.048	
	6.00	152	6.831	109.4	7.785	124.7	17.3790	118.2	0.114	0.130	0.123	
	4.00	102	10.84	173.6	11.44	183.3	111.131	178.3	0.181	0.191	0.186	
	3.00	76	13.25	212.2	14.27	228.6	113.67	219.0	0.222	0.239	0.229	
	2.00	51	16.5	264.3	17.31	277.3	116.899	270.7	0.276	0.290	0.283	
	1.25	32	18.68	299.2	19.62	314.3	119.267	308.6	0.313	0.329	0.323	

NOTE - GAMMA-RAY SCAN FOR 14 INCH HORIZONTAL POSITION ABOVE TRAY 5 IN QUESTION
DUE TO INTERFERENCE OF DOWNCOMER APRON AND LIQUID IN DOWNCOMER.

88 July-August Progress Report
Page 48

TABLE V (CONT'D)
PROCESS AND FROTH DENSITIES
TRACE TOLUENE IN WATER

RUN INFORMATION	ELEVATION		DENSITY FROM GAMMA-RAY SCAN						LIQUID FRACTION			
	ABOVE TRAY-4		Low		High		Average		Low	High	Average	
	inches	mm	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³	lb/ft ³	kg/m ³				
Run : 16557	40.90	1039										
	39.00	991										
Horizontal Position: 20 508	37.00	940										
	35.00	889	23.65	378.8	25.54	409.1	124.874	398.5	0.396	0.428	0.417	
	33.00	838	47.38	759.0	47.93	767.8	147.684	763.8	0.795	0.804	0.800	
	31.00	787	56.07	898.2	57.01	913.2	156.503	905.1	0.941	0.957	0.948	
	30.00	762	57.03	913.5	57.38	919.1	157.203	916.3	0.957	0.963	0.960	
	29.00	737	56.43	903.9	56.78	909.5	156.632	907.2	0.947	0.953	0.950	
Temperature : deg. F deg. C	28.25	718	54.86	878.8	55.13	883.1	155.007	881.1	0.921	0.925	0.923	
	26.00	660	21.38	342.5	23.9	382.8	122.979	368.1	0.358	0.401	0.385	
Tray 4 : 216.8 102.7	24.00	610										
	22.00	559	-0.225	-3.6	10.0724	1.2	-0.155	-2.5	-0.004	0.001	-0.003	
	20.00	508	10.3126	5.0	10.3934	6.3	10.3584	5.7	0.005	0.006	0.005	
	18.00	457	0.517	8.3	10.6165	9.9	10.5806	9.3	0.008	0.010	0.009	
Density : lb/ft ³ kg/m ³	16.00	406	10.4794	7.7	10.5375	8.6	10.5073	8.1	0.007	0.008	0.008	
	14.00	356	10.7409	11.9	10.7681	12.3	10.7558	12.1	0.012	0.012	0.012	
Liquid : 59.59 955	12.00	305	10.6361	10.2	0.733	11.7	10.6884	11.0	0.010	0.012	0.011	
Vapor : 0.0408 0.654	10.00	254	10.0041	0.1	10.0755	1.2	10.0392	0.6	-0.001	0.001	-0.000	
	8.00	203	10.8904	14.3	1.028	16.5	10.9774	15.7	0.014	0.017	0.016	
	6.00	152	1.834	29.4	1.961	31.4	11.8876	30.2	0.030	0.032	0.031	
	4.00	102	3.654	58.5	4.17	66.8	13.8360	61.4	0.061	0.069	0.064	
	3.00	76	4.841	77.5	5.7	91.3	15.3089	85.0	0.081	0.095	0.088	
	2.00	51	8.483	135.9	9.503	152.2	18.8026	141.0	0.142	0.159	0.147	
	1.25	32	12.04	192.9	13.05	209.0	12.521	200.6	0.202	0.218	0.210	

NOTE - SCAN AT 26 INCH ELEVATION FOR 20 INCH HORIZONTAL POSITION
QUESTIONABLE DUE TO INTERFERENCE FROM LIQUID IN DOWNCOMER

APPENDIX L

APPENDIX L

MAR 5 1 1988

NOTE TO: Jerry Schroy, Monsanto
FROM: Jan Meyer, SDB
RE: VOL 1B, Table D-2 References

We have tracked down many of the missing references for Table D-2, and so far have found very little information that could be of use to us. Briefly, what we have found is -

1. We have not been able to locate the source of several of the entries in Table D-2. Since this Table was borrowed from another project, we are not certain of the reasons for the problem - the information may be either CBI or the items were incorrectly referenced.
2. For those entries where the reference was located, we found a majority of the strippers to be packed beds. In many of the cases involving tray designs, the reference did not have any information on the column design.
3. The references for the sites listed on p.D-4 appear to all be from the BACT/LAER document and from site visits. Sites A, B, and G are from the BACT/LAER document. Site A has an unknown design, while B and G are packed bed strippers. The TSDf report also presents the results for sites B and G. The trip reports for the other sites are largely CBI, and thus not easily used. The available nonCBI reports lack critical information on the strippers design. Consequently, I think this is not real productive to persue.
4. The references for the sites listed on p. D-5 appear to all be from §114 responses. The docket contains information on 7 strippers, and 3 of the 7 had trays internals. Attached are copies of the information provided on each of these three strippers. I will mail you a copy of the docket information on the 4 packed bed strippers.

At this point, I suspect that the best next step might be to see if anyone in CMA has data on stripper performance that they are willing to analyse or get the toluene data from the Fractionation Institute. Let me know if there are additional references or ideas on sources of data that you want to persue.

cc: Mary Tom Kissel
Elaine Manning

II-D-24

OxyChem

April 30, 1990

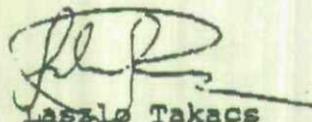
Ms. Penny Lassiter
US Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Standards Division
Research Triangle Park, NC 27711

Dear Ms. Lassiter:

Per Mr. Jack R. Farmers' request dated March 16, 1990, Occidental Chemical Corporation is hereby submitting the completed Table a of Enclosure 2 of the above dated information package for the waste water collection and treatment systems located at its Convent, LA and Chocolate Bayou, TX facilities.

If you need additional technical information, you may want to call our plant contacts directly (Kelley Ewen at Convent - [504-562-9271] and Steve Jackson at Chocolate Bayou - [713-393-5404]) or, for any information, me at (716) 286-3103.

Sincerely,



Laszlo Takacs
Manager - Air Quality



Occidental Chemical Corporation

Corporate Environmental Affairs

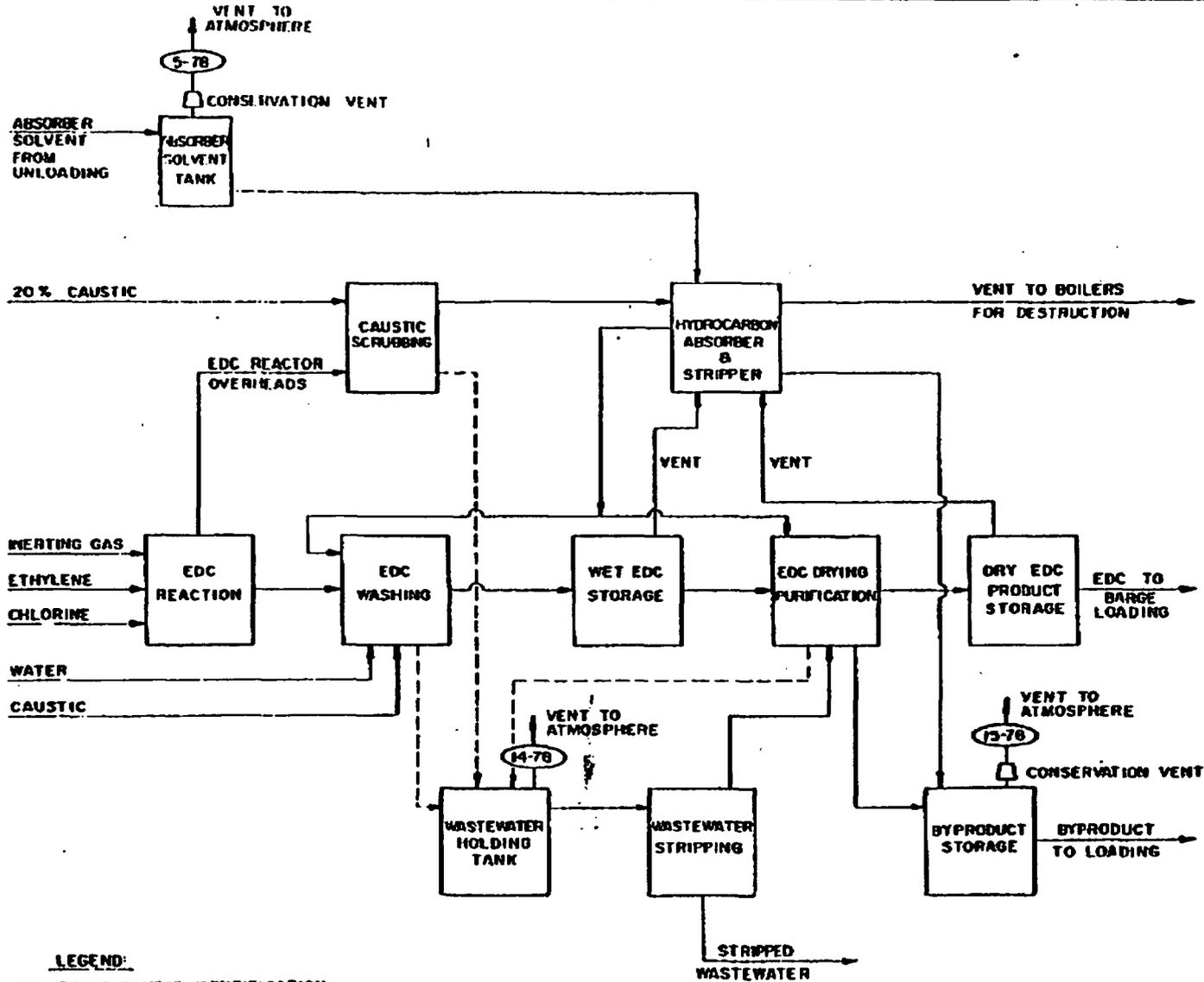
Occidental Chemical Center

360 Rainbow Boulevard South, P.O. Box 728, Niagara Falls, NY 14302-0728

716/286-3000

SECTION A II

L-3



LEGEND:
 (14-78) POINT SOURCE IDENTIFICATION NUMBER

FIGURE 4
 OCCIDENTAL CHEMICAL CORPORATION
 CONVENT, LOUISIANA
 CONSOLIDATED AIR PERMIT APPLICATION
 BLOCK FLOW DIAGRAM
 ETHYLENE DICHLORIDE FACILITY
 ST. JAMES PARISH
C-K ASSOCIATES, INC.
 BATON ROUGE, LOUISIANA

TABLE 2-4. STEAM STRIPPING - STRIPPER AND AUXILIARY EQUIPMENT DESIGN

Steam Stripping ID ^a	Waste Water Stripper		
Column Operating Variables			
Pressure Drop (psig) ^b		3.5 psig max	
Temperature (°F) ^b		225 degrees F	
Steam/Feed Ratio ^c		0.113 $\frac{\text{lbs steam}}{\text{lbs feed}}$	
Steam Temperature (°F) ^b		282 degrees F	
Steam Pressure (psig) ^b		22.4 psig in column	
Column Dimensions:			
Diameter (ft) ^b		3 ft	
Height (ft) ^b		45 ft 6 in	
Internals:			
Trays (number, type)		20 sieve trays	
Packing (type)			
Design Efficiency, % (Specify by chemical)		99.8% removal of EDC	

Stripped Organics Destination^d Recycle to process

^aUse the same identification that was used in the flow diagram.

^bInclude units if not same as requested.

^cSpecify units.

^dRecycle to Process, Incineration, etc.

SECTION D I, II & III

TABLE 2-7. TREATMENT SYSTEM INFLUENT AND EFFLUENT WASTEWATER STREAM DATA

Wastewater Stream ID ^a	Wastewater Flow Rate ^b		Compound ^c	Annual Average Organic Concentration (mg/l) ^c	Basis ^d
	Flow Rate	Basis			
Waste Water Stripper Bottoms	73.78 gpm	E ¹	0-72 TOC	0.649 unknown	M ²
Waste Water from Biological System	73.78 gpm	E ³	0-72 TOC	unknown unknown	M ⁶
Combined Discharge	496 gpm	M ⁴	0-72 TOC	0.025 unknown	M ⁵ M ⁷

- 1 Flow is measured continuously at the biological discharge and is assumed to be the same at this point in the process (neglecting any evaporation losses).
- 2 Measured by GC
- 3 Flow is measured continuously at the combined discharge and the biological discharge and the waste water from the pond is estimated based on the difference.
- 4 Flow is measured continuously.
- 5 Measured by Method 505A 16th ED of STD Methods.
- 6 Based on 6 recent (3-90) samples by Method 601 16th ED STD Methods.
- 7 Based on 6 recent (3-90) samples by Method 601 16th ED STD Methods.

TOC - Total Organic Compounds - a conventional pollutant

^aSee Section D Instructions (#1).
^bSee Section D Instructions (#2).
^cSee Section D Instructions (#3).

20R-100



ESTABLISHED 1802

E. I. DU PONT DE NEMOURS & COMPANY

INCORPORATED

BEAUMONT WORKS

P. O. BOX 3269, BEAUMONT, TEXAS 77704

RAIL ADDRESS, DOWLING, TEXAS

409 / 722-3451

A-90-23
II-D-38

May 24, 1990

Ms. Penny Lassiter
Office of Air Quality Planning and Standards
U. S. Environmental Protection Agency
Research Triangle Park, N.C. 27711

Re: EPA Questionnaire - VOC and HAP

Dear Ms. Lassiter:

Attached are the tables for the Du Pont Beaumont, Texas site per your March 16, 1990 request. Sections 2A, B and C have been completed for the following processes:

NB - Nitrobenzene
ME - Methanol
AC - Acrylonitrile/Acetonitrile
AN - Aniline

Section 2D has been completed for the entire facility treatment system. In addition, we have updated Table 1-5a, "Identification of Process Units Which Produce or Use HAP's". Please note that the production capacity and actual amounts are confidential. In order to make this easier for you to handle, we have included duplicate pages, but the one with the production number is marked "Confidential".

Should you have any questions, please telephone me at (409) 727-9295.

Very truly yours,

R. L. McClure
Environmental Superintendent

RLM/bdr
(HD7.10)

*Removed
to
Confidential
file*

PROCESS ID - NB
SECTION C
INFORMATION ON ORGANIC RECOVERY/REMOVAL OPERATIONS

TABLE 2-4. STEAM STRIPPING - STRIPPER AND AUXILIARY EQUIPMENT

Steam Stripping ID ^a	ANT 1 Steam Stripper
Column Operating Variables	
Pressure Drop (psig) ^b	60 inches of W.C.
Temperature (°F) ^b	108 °C
Steam/Feed Ratio ^c	0.625
Steam Temperature (°F) ^b	260°F
Steam Pressure (psig) ^b	20.3 psig
Column Dimensions:	
Diameter (ft) ^b	6'
Height (ft) ^b	38'
Internals:	
Trays (number, type)	20, Ballast trays
Packing (type)	
Height (ft) ^b	
Design Efficiency, % (Specify by chemical)	99% Benzene 99% Nitrobenzene 99% Aniline
Stripped Organics Destination ^d	Burned at powerhouse and recycled to process

^aUse the same identification that was used in the flow diagram.
^bInclude units if not same as requested.
^cSpecify units.
^dRecycle to Process, Incineration, etc.

TABLE 2-4. STEAM STRIPPING - AUXILIARY EQUIPMENT DESIGN (Continued)

Steam Stripper ID ^a	ANTI Steam Stripper
System Tanks	Decanter
List and specify type, ^b	Decanter
Volume (gal) ^c	5,000 gal.
Hold-up time (min) ^c	variable
Heat Exchangers	Calandria
List and specify surface area, ft ² ^c	Shell and tube
	Surface area 1,900 ft ²
Pumps	
List and specify hp	Bottoms pump - 20 hp
	Decanter pump - 1 hp
	Reflux Pump - 7.5 hp
Condensers	
List and specify type	Feed Preheater - shell & tube
	Subcooler - shell & tube
	#1 & H2 Cooler - shell & tube
Other system components	
List and specify	
Utility Usage	
Steam (psig, lb/yr) ^c	175 psig, 71.2MM ppyr/20 psig
	30MM ppyr
Electricity (kw-hr/yr) ^c	Not measured
Cooling Water (gal/yr) ^c	14.7MM gal. yr.
Process air (ft ³ /yr) ^c	1MM ft ³ /yr
Other (specify)	
Nitrogen	2.6MM ft ³ /yr

^aUse the I.D. used in the flow diagram.
^bFeed tank, treated wastewater surge tank, etc.
^cSpecify units if different from the units listed.

PROCESS ID - AN
SECTION C
INFORMATION ON ORGANIC RECOVERY/REMOVAL OPERATIONS

TABLE 2-4. STEAM STRIPPING - STRIPPER AND AUXILIARY EQUIPMENT DESIGN

Steam Stripping ID^a | ANT 2 Waste Water Column |

Column Operating Variables

Pressure Drop (psig) ^b	62 inches of W.C.
Temperature (°F) ^b	111°C
Steam/Feed Ratio ^c	Not applicable
Steam Temperature (°F) ^b	377 OF
Steam Pressure (psig) ^b	175 psig

Column Dimensions:

Diameter (ft) ^b	3' 6"
Height (ft) ^b	39'

Internals:

Trays (number, type)	18, valve trays
Packing (type)	

Design Efficiency, %

(Specify by chemical)	99% Benzene
	99% Nitrobenzene
	99% Aniline

Stripped Organics Destination^d

	Burned in powerhouse
--	----------------------

^aUse the same identification that was used in the flow diagram.

^bInclude units if not same as requested.

^cSpecify units.

^dRecycle to Process, Incineration, etc.

TABLE 2-4. STEAM STRIPPING - STRIPPER AND AUXILIARY EQUIPMENT DESIGN

Steam Stripping ID ^a	ANT 2 Waste Water Column
System Tanks	
List and specify type, ^b	Decanter
Volume (gal) ^c	1,200 gal.
Hold-up time (min) ^c	variable
Heat exchangers	
List and specify surface area, ft ²) ^c	Reboiler
	Shell & tube, 800 ft ²
Pumps	
List and specify hp	Feed pump - 5 hp
	Decanter pump - 2 hp
	Bottoms pump - 10 hp
Condensers	
List and specify type	O/H condenser - shell & tube
Other System components	
List and specify	Downstream - carbon absorber
Utility Usage	
Steam (psig, lb/yr) ^c	175 psig, usage not measured
Electricity (kw-hr/yr) ^c	Not measured
Water (gal/yr) ^c	Not measured
Process air (ft ³ /yr) ^c	1MM ft ³ /yr
Other (specify)	
Nitrogen	2.6MM ft ³ /yr

^aUse the I.D. used in the flow diagram.
^bFeed tank, treated wastewater surge tank, etc.
^cSpecify units if different from the units listed.

APPENDIX M

EXXON CHEMICAL COMPANY

APPENDIX M



Environmental Technical Services
Baytown, Texas

April 1, 1993

Dr. Jan Meyer
USEPA
Office of Air Quality Planning and Standards
ESD (MD-13)
Research Triangle Park, NC 27711

Dear Dr. Meyer:

At the last HON Wastewater Work Group Meeting on March 24, I agreed to send you our results so far related to steam stripper ASPEN simulation studies. The work we've done to date is attached. The objective of this work, from Exxon Chemical's perspective, was to show that a variety of steam stripper process conditions could be used in practice to achieve a uniform VOHAP removal target. We have specifically examined the question of vacuum steam stripping as an alternate, or in addition to, EPA's specification for an atmospheric steam stripping system.

One of the major results of this work is the conclusion that EPA's specification of 0.096 lbs steam per lbs feed in the HON proposal for reference control technology is too high. For the benzene water system used in the BID, using ASPEN, the attached calculations show that a steam to feed ratio of 0.0156 will produce a 99 % benzene removal at atmospheric conditions. The attached work also shows that operations down to pressures of 2 psia will produce a 99 % benzene removal at lower steam to feed ratios.

Jerry Schroy, Monsanto, is planning to do similar calculations with another process simulation package besides ASPEN. If you, your staff or your contractors have any questions regarding this work, please feel free to call me at 713-425-5343. I can do additional, limited, simulation studies if you feel this information will be helpful in formulating a basis for steam stripping reference control technology.

By the way, I reviewed the computer results of the EPA case and found that the information I reported verbally in our meeting on the 24th was not correct. The overhead concentration of benzene was not 1000 ppm, as I reported verbally, but is roughly 6570 ppm. This does not change my conclusion, which is, the steam to feed ratio is too high and if the overhead stream were recycled, too much benzene would go with the water phase, roughly 25 % of the incoming benzene by my calculations.

I appreciate the opportunity to be able to submit this work. Please feel free to circulate this work to the members of the HON Work Group.

Yours truly,

A handwritten signature in cursive script that reads "Bruce C. Davis".

Bruce C. Davis

EVBDP004

cc: CMA Secondary Emissions Work Group

P.O. Box 400, Baytown, Texas 77522-0400
Fax: (713) 425-2802

bcc: A. Bogard BWCP
C. B. Barbre BRCP CPMO-4
J. D. Reese BRCP CPMO-3
G. Hope BRCP CPWO-2
S. N. Labat BRCP CPSE
W. F. Buchholtz BTCP CAB-4
A. A. Lundgren BOP
C. L. Gleason BOP
N. L. Morrow BRCP CPWO-2 & ECA HOF KTY FWY
B. L. Taranto ECA HOF KTY FWY
G. M. Brown BCT E-137
R. P. Herbst BCT E-135
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Comments on the EPA Basis for Steam Stripper Reference Control Technology

Prepared by: B. C. Davis, Exxon Chemical Co., March 31, 1993

Background

The EPA has proposed steam stripper as reference control technology for the Wastewater HON. If a steam stripper is designed and operated to the EPA specifications, no performance testing is required, only monitoring of process variables is needed to assure desired removal performance is occurring.

The EPA specifications, as proposed Dec. 91, 1992 FR 57:252 63.138 (f), for Steam Stripper Reference Control Technology are:

1. Minimum active column height - 5 m
2. Counter current flow - min 10 theoretical trays
3. Minimum steam flow - 0.096 kg steam/l ww flow
4. Minimum ww feed temp - 35 °C.
5. Maximum liquid loading of 39,900 l/hr-m²
6. Water cooled Condenser vapor outlet temp - 50 °C

This information is not enough to fully simulate the system, the feed temperature to the column is needed. Per discussions with the EPA, a bottoms to feed heat exchanger is used to develop a 95 °F feed temperature to the column. This temperature was used as the basis for these studies.

The EPA used an unspecified process simulation package to derive these specifications. In the BID document, the EPA used benzene/water as a case study upon which these specifications were derived.

Purpose of this Work

The purpose of this work is to review EPA's steam stripping reference control technology specifications and demonstrate via computer process simulation studies that a steam stripper operating at different conditions can achieve the desired VOHAP removal.

The system chosen for these studies is the same system used by EPA in the BID, that is the benzene/water system.

Problem Basis Statement:

Feed Flow	300 gal/min
Contamination	500 ppm Benzene
Removal Target	99 %

Number of Equilibrium Stages	5
Murphree Tray Efficiency	80
Data Source for Properties	DIPPR
Process Simulation Package	ASPEN Release 8.4-1

Case Set up

Counter current operations with steam fed to the bottom of the tower and contaminated water fed to the top of the tower. Stream 1 is the overhead product, Stream 2 is the bottoms product, Stream 3 is the contaminated water feed and Stream 4 is the steam feed.

The steam is 100 psig saturated steam. For the atmospheric stripper design case, the liquid feed temperature was set at 95 °C (203 °F). This is based on discussions with EPA about the feed temperature to the column following a feed to bottom heat exchanger. For the vacuum steam stripping cases, the feed temperature was set at a 15 degree temperature approach to the bottoms temperature. The atmospheric case feed temperature of 95 °C corresponds to a 22 degree F approach to the bottoms temperature. This temperature approach would be achieved with a liquid feed to bottoms heat exchanger.

Results

The ASPEN results are summarized below for a uniform removal of 99 % benzene from the feed. The various computer runs are summarized in the attachments.

Tower Pressure psia	Steam Rate lbs/hr	Steam/ Feed Ratio
16	14400	0.0960
16	4000	0.0267
16	2346	0.0156
14	2311	0.0154
12	2296	0.0153
10	2245	0.0150
7.5	2193	0.0146
5	2191	0.0141
2	1990	0.0133

Analysis/Comments

1. The steam to feed ratio specified as reference control technology by the EPA (0.096) is too high for this system. If this amount of steam were used, too much water would be carried overhead resulting in too dilute an overhead stream, resulting in difficulty splitting the benzene/water mixture.

If the water in the overhead stream is recycled back to the feed, which is a common disposition for this stream, too much water would need to be recycled. At the EPA proposed steam/feed ratio of 0.096, ~25 % of the recovered benzene would need to be recycled with the overhead water phase to the stripper feed. ~75 % of the benzene would be separated in a phase split and sent to residual recovery or treatment. The overhead condensed water stream represents a recycle stream which is 7.5 % of the water column feed stream.

2. This study does not focus on the removal efficiencies achievable for various VOHAP's. For benzene, 99 % removal at a 500 ppm inlet concentration is possible. Other VOHAPS's will have different removal efficiencies when stripped at a constant steam to feed ratio and a fixed number of equilibrium stages. The issue of VOHAP removal efficiency variation for steam stripping technology will be fully discussed in forthcoming CMA comments on the HON.
3. The choice of tray efficiency is based on experience and available performance data for the design basis mix of compounds and compositions as well as details about the column internals. The choice of an 80 % Murphree tray efficiency was chosen because this is the value EPA used in the studies done to support the BID. A choice of efficiency is based on design experience and depends on whether vapor liquid equilibrium or mass transfer is controlling the separation. The choice of tray efficiency is also a function of the tray or packing type and design. The issue of the choice of tray efficiency will be developed fully in CMA comments and will not be discussed here.
4. The minimum steam to feed ratio to achieve a benzene removal of 99 % with 5 equilibrium stages is 0.0156. This is greater than a factor of six reduction in steam usage, compared to EPA's proposed specifications, to achieve the desired removal. Further, the overhead stream has a minimum amount of water and maximizes the benzene water separation. At the EPA steam/feed ratio of 0.096, 11,426 lbs/hr of water are sent overhead which is recycled to the tower feed. As stated above, the benzene contained at it's solubility in this recycle stream is roughly 25 % of the incoming benzene fed to the tower.

At the minimum steam/feed ratio needed to achieve the removal specification (99 %), 50.5 lbs/hr of water is sent overhead. This results in a small water stream to recycle (0.03 % of the water feed). Over 99.8 % of the benzene taken overhead can be separated from the overhead stream by decanting the overhead mixture.

5. The concept of specifying a uniform steam to feed mass ratio for all columns and all mixes of chemicals will not result in the best operating scenario for any one individual system. For the model case of a benzene/water system at 500 ppm, the EPA design steam rate is over 6 times too high.
6. The EPA has specified other parameters for the design steam stripper including active column height, the number of theoretical stages, the minimum steam to feed ratio, the waste water feed temperature, the maximum liquid loading, and the water cooled vapor outlet temperature.

All of these parameters do not need to be specified to meet EPA's objective of a performance standard. All that is needed is the minimum number of equilibrium stages and the steam to feed ratio or the vapor overhead to feed ratio. This ratio needs to be coupled to a wastewater feed temperature, but the ratio should be allowed to be equivalent to any feed temperature. The other parameters are not needed. The active column height is a function of the internal column design and is not needed if the equilibrium stages are specified. The same is true for the column liquid loading. The outlet vapor temperature and the restriction to water cooling should not be specified, particularly in view of the fact that any non-condensed material coming out of the column would need further treatment.

7. Steam stripping at vacuum conditions has a number of advantages over the operations at atmospheric conditions. These advantages include:
 - 7.1 A lower steam to feed ratio is possible to achieve the same removal efficiency. For the benzene water system examined here, an approximate 15 % savings in steam is possible at 2 psia compared to the minimum steam operations at atmospheric conditions.
 - 7.2 Mineral scaling and fouling in the tower are minimized at vacuum conditions when compared to atmospheric operations. The amount of scaling and fouling is dependent on the temperature of the system. At 2 psia, the bottoms temperature is approximately 127°F; at 16 psia the bottoms temperature is approximately 216°F. The reduced potential for scaling and fouling has implications for better service factors and stripping performance for a vacuum system as compared to an atmospheric system.

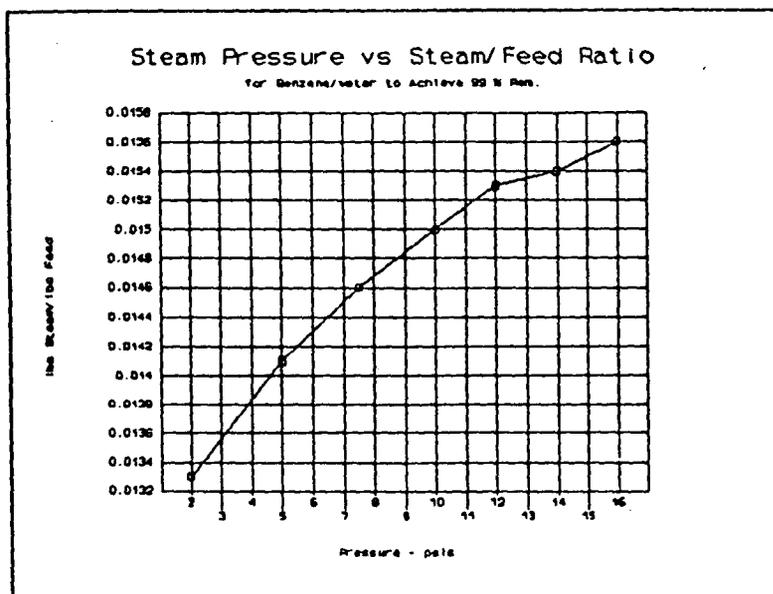
Conclusions/Recommendations

1. The concept of specifying a uniform steam to feed mass ratio for all columns and all mixes of chemicals will not result in the best operating scenario for any one individual system. We conclude that one set of generic parameters to set the design parameters for all steam strippers will not work. We recommend that case by case (system by system) performance and operating parameters be determined through the use of process simulation modelling studies.

This approach will allow for the use of other types of steam strippers or other operating conditions as demonstrated by a process simulation model. The operating and design conditions would be established using the VOHAP removal goals established in the rules. We understand that the EPA is considering chemical specific removal goals and that CMA will propose such an approach in forthcoming HON comments. In addition to steam stripping, the process simulation modelling approach will allow for other types of stripping, besides steam stripping, to be used to accomplish the desired removal performance.

2. For the benzene/water system examined in these studies, a range of steam to feed ratios is possible to achieve a 99 % removal. Steam Strippers operating at vacuum conditions down too as low as 2 psia, can achieve 99 % benzene removal at lower steam to feed ratios as compared to an atmospheric system. For the atmospheric pressure case, the minimum steam to feed ratio is 0.0156 and this ratio ranges to as low as 0.0133 for a

vacuum steam stripper operating at 2 psia. The performance curve to achieve 99 % benzene removal at varying steam pressures is shown below:



3. For the reasons discussed in item 6 above, the only parameters the EPA needs to specify is the removal efficiency and the minimum number of equilibrium stages. The steam to feed ratio or the vapor overhead to feed ratio can be specified and tied to an inlet temperature. Any equivalent steam ratio should be allowed, independent of the inlet temperature. The steam ratio should be expressed as a range and can be tied to system pressure. Any other steam stripper column or performance parameters do not need to be specified to achieve EPA's removal performance goals.

Attachment 1

Calculation Summaries of ASPEN Computer Simulations

Atmospheric Steam Stripper – ASPEN Results
EPA's Design Case

Stream Name	Overhead Product	Bottoms Contaminated Product	Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9608	0.000036	0.9601	0
Water	634.2571	8491.470	8326.3946	799.3338
Mole Fraction	0.001512	0.000000	0.00011529	0
Total Flow	635.2179	8491.470	8327.3547	799.3338
Components – lb/hr				
Benzene	75.0522	0.002839	75	0
Water	11426	152970	150000	14400
Wgt ppm	6568.545	0.018564	500	0
Total Flow	11501.05	152970.0	150075	14400
V/L Molar				0.095988
V/L Weight				0.095952
Recycle – lb/hr				
Benzene	19.4242			
Percent of Feed	25.88092	Percent to Residual		74.11907
Wgt ppm	1700			
Water	11426			
Percent of Feed	7.617333			

Atmospheric Steam Stripper – ASPEN Results
Minimum Steam to Achieve 99 % Removal

Stream Name	Overhead Product	Bottoms Contaminated Product	Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9505	0.009595	0.9601	0
Water	2.8044	8453.815	8326.3946	130.225
Mole Fraction	0.253135	0.000001	0.00011529	0
Total Flow	3.7549	8453.825	8327.3547	130.225
Components – lb/hr				
Benzene	74.2504	0.7495	75	0
Water	50.5217	152300	150000	2346.009
Wgt ppm	1469673.	4.921208	500	0
Total Flow	124.7721	152300.7	150075	2346.009
V/L Molar				0.015638
V/L Weight				0.015632
Recycle – lb/hr				
Benzene	0.085886			
Percent of Feed	0.115671	Percent to Residual		99.88432
Wgt ppm	1700			
Water	50.5217			
Percent of Feed	0.033681			

Steam Stripper – ASPEN Results
Vacuum Stripper @ 2 psia

Stream Name	Overhead Product	Bottoms Product	Contaminated Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9505	0.009601	0.9601	0
Water	2.2063	8464.673	8326.3946	110.4857
Mole Fraction	0.301096	0.000001	0.00011529	0
Total Flow	3.1568	8464.683	8327.3547	110.4857
Components – lb/hr				
Benzene	74.2499	0.75	75	0
Water	39.7481	151950	150000	1990.4
Wgt ppm	1868011.	4.935834	500	0
Total Flow	113.998	151950.7	150075	1990.4
V/L Molar				0.013267
V/L Weight				0.013262
Recycle – lb/hr				
Benzene	0.067571			
Percent of Feed	0.091005	Percent to Residual		99.90899
Wgt ppm	1700			
Water	39.7481			
Percent of Feed	0.026498			

Steam Stripper – ASPEN Results
Vacuum Stripper @ 5 psia

Stream Name	Overhead Product	Bottoms Product	Contaminated Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9505	0.009601	0.9601	0
Water	2.2862	8441.842	8326.3946	117.7336
Mole Fraction	0.293663	0.000001	0.00011529	0
Total Flow	3.2367	8441.851	8327.3547	117.7336
Components – lb/hr				
Benzene	74.25	0.75	75	0
Water	41.1862	152080	150000	2120.97
Wgt ppm	1802788.	4.931614	500	0
Total Flow	115.4362	152080.7	150075	2120.97
V/L Molar				0.014138
V/L Weight				0.014132
Recycle – lb/hr				
Benzene	0.070016			
Percent of Feed	0.094298	Percent to Residual		99.90570
Wgt ppm	1700			
Water	41.1862			
Percent of Feed	0.027457			

Steam Stripper – ASPEN Results
 Vacuum Stripper @ 7.5 psia

Stream Name	Overhead Product	Bottoms Product	Contaminated Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9505	0.009601	0.9601	0
Water	2.4292	8445.71	8326.3946	121.7445
Mole Fraction	0.281237	0.000001	0.00011529	0
Total Flow	3.3797	8445.719	8327.3547	121.7445
Components – lb/hr				
Benzene	74.25	0.75	75	0
Water	43.7627	152150	150000	2193.228
Wgt ppm	1696650.	4.929346	500	0
Total Flow	118.0127	152150.7	150075	2193.228
V/L Molar				0.014619
V/L Weight				0.014614
Recycle – lb/hr				
Benzene	0.074396			
Percent of Feed	0.100197	Percent to Residual		99.89980
Wgt ppm	1700			
Water	43.7627			
Percent of Feed	0.029175			

Steam Stripper – ASPEN Results
 Vacuum Stripper @ 10 psia

Stream Name	Overhead Product	Bottoms Product	Contaminated Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9505	0.009601	0.9601	0
Water	2.5595	8448.433	8326.3946	124.5985
Mole Fraction	0.270797	0.000001	0.00011529	0
Total Flow	3.51	8448.443	8327.3547	124.5985
Components – lb/hr				
Benzene	74.25	0.75	75	0
Water	46.1107	152200	150000	2244.642
Wgt ppm	1610255.	4.927726	500	0
Total Flow	120.3607	152200.7	150075	2244.642
V/L Molar				0.014962
V/L Weight				0.014956
Recycle – lb/hr				
Benzene	0.078388			
Percent of Feed	0.105573	Percent to Residual		99.89442
Wgt ppm	1700			
Water	46.1107			
Percent of Feed	0.030740			

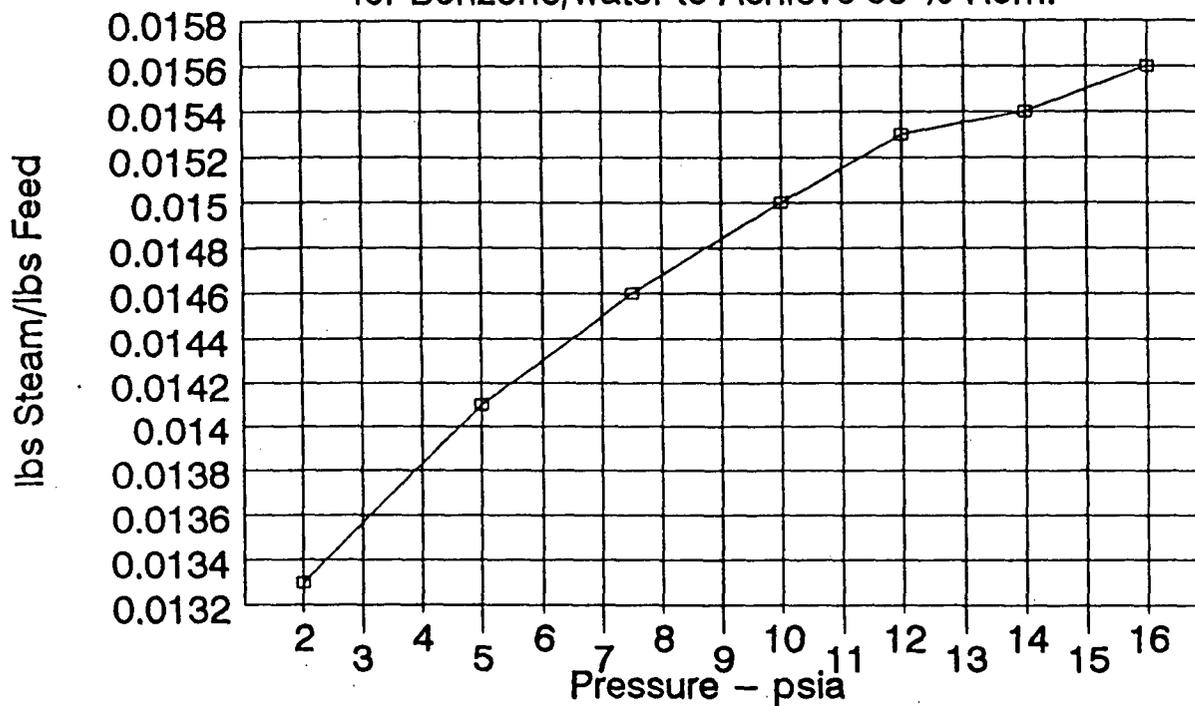
Steam Stripper – ASPEN Results
 Vacuum Stripper @ 12 psia

Stream Name	Overhead Product	Bottoms Product	Contaminated Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9505	0.009601	0.9601	0
Water	2.6283	8451.229	8326.3946	127.4634
Mole Fraction	0.265591	0.000001	0.00011529	0
Total Flow	3.5788	8451.239	8327.3547	127.4634
Components – lb/hr				
Benzene	74.25	0.75	75	0
Water	47.3493	152250	150000	2296.253
Wgt ppm	1568133.	4.926108	500	0
Total Flow	121.5993	152250.7	150075	2296.253
V/L Molar				0.015306
V/L Weight				0.015300
Recycle – lb/hr				
Benzene	0.080493			
Percent of Feed	0.108409	Percent to Residual		99.89159
Wgt ppm	1700			
Water	47.3493			
Percent of Feed	0.031566			

Steam Stripper – ASPEN Results
 Vacuum Stripper @ 14 psia

Stream Name	Overhead Product	Bottoms Product	Contaminated Feed	Steam
Stream ID	1	2	3	4
Components – lbmol/hr				
Benzene	0.9505	0.009593	0.9601	0
Water	2.7358	8451.948	8326.3946	128.2898
Mole Fraction	0.257846	0.000001	0.00011529	0
Total Flow	3.6863	8451.958	8327.3547	128.2898
Components – lb/hr				
Benzene	74.2506	0.7493	75	0
Water	49.2858	152260	150000	2311.141
Wgt ppm	1506531.	4.921187	500	0
Total Flow	123.5364	152260.7	150075	2311.141
V/L Molar				0.015405
V/L Weight				0.015399
Recycle – lb/hr				
Benzene	0.083785			
Percent of Feed	0.112841	Percent to Residual		99.88715
Wgt ppm	1700			
Water	49.2858			
Percent of Feed	0.032857			

Steam Pressure vs Steam/Feed Ratio for Benzene/water to Achieve 99 % Rem.



Comments:

1. A steam/feed ratio of 0.0156 is needed at atmospheric conditions to achieve a 99 + % benzene removal compared to a steam/feed ratio of 0.0133 to achieve the same removal at a steam pressure of 2 psig. This represents a steam savings of ~ 15 % for the vacuum case.

Attachment 2
ASPEN Computer Simulations

ORIGINAL RUN
3:13:38 P.M.

JULY 4, 1991
THURSDAY

INPUT FILE: RUN1.inp

OUTPUT PDF: RUN1 VERSION: 1

LOCATED IN: C:\ASPEN\RUN1

PDF SIZE: FILE (PSIZE)=99999 RECORDS. IN-CORE = 400 RECORDS.

```

1      ;
2      ;Input file created by ModelManager Rel. 3.2-1 on Thu Jul 4 15:12:20 1
3      ;Directory C:\ASPEN Runid RUN1
4      ;
5
6
7      SUMMARY MM
8
9      IN-UNITS ENG
10
11     DEF-STREAMS CONVEN ALL
12
13     TITLE "CHEMICAL MANUFACTURERS ASSOC. SIMULATION STUDIES"
14
15     DATABANKS ASPENPCD / DIPRPCD
16
17     PROP-SOURCES ASPENPCD / DIPRPCD
18
19     COMPONENTS
20         C6H6 C6H6 C6H6 /
21         H2O H2O H2O
22
23     HENRY-COMPS LIST1 C6H6 H2O
24
25     FLOWSHEET
26         BLOCK B1 IN=3 4 OUT=1 2
27
28     PROPERTIES SYSOP11A HENRY-COMPS=LIST1
29
30     PROP-DATA
31         IN-UNITS SI
32         PROP-LIST GMUQB
33         BPVAL C6H6 H2O -879.4033
34         BPVAL H2O C6H6 -363.7491
35
36     PROP-DATA
37         IN-UNITS SI
38         PROP-LIST GMUQA
39         BPVAL C6H6 H2O -.7254485E-01
40         BPVAL H2O C6H6 .8297351E-02
41
42     PROP-DATA
43         IN-UNITS SI
44         PROP-LIST HENRY
45         BPVAL C6H6 H2O 73.157 -6276 -8.4443 6.26E-06 278.68 &
46             562.16
47
48     STREAM 3
49         SUBSTREAM MIXED TEMP=203 PRES=16
50         MASS-FLOW C6H6 75 / H2O 150000
51
52     STREAM 4
53         SUBSTREAM MIXED PRES=100 VFRAC=1
54         MASS-FLOW H2O 14400
55
56     BLOCK B1 RADFRAC
57         PARAM NSTAGE=10 EFF=MURPHREE
58         FEEDS 3 1 ON-STAGE / 4 10 ON-STAGE

```

59 PRODUCTS 1 1 V / 2 10 L
 60 P-SPEC 1 16
 61 COL-SPECS Q1=0 QN=0 DP-COL=3 MASS-RDV=1
 62 STAGE-EFF 1 .8 / 10 .8
 63 T-EST 1 215 / 10 226

64
 65 STREAM-REPOR MOLEFLOW MASSFLOW
 66
 67 PROPERTY-REP PARAMS PCES PROP-DATA
 68 ;
 69 ;
 70 ;
 71 ;
 72 ;

*** INPUT TRANSLATOR MESSAGES ***

THIS VERSION OF ASPEN PLUS LICENSED TO AWD TECHNOLOGIES, INC.

*** FLOWSHEET ANALYSIS MESSAGES ***

FLOWSHEET CONNECTIVITY BY STREAMS

STREAM	SOURCE	DEST	STREAM	SOURCE	DEST
4	----	B1	3	----	B1
1	B1	----	2	B1	----

FLOWSHEET CONNECTIVITY BY BLOCKS

BLOCK	INLETS	OUTLETS
B1	3 4	1 2

COMPUTATION ORDER FOR THE FLOWSHEET IS:

B1

INFORMATION DURING PROGRAM GENERATION (OLDMOD.6)
 PP COMMON MISSING, OR TOO SMALL: GMUQR
 NEW LENGTH = 2 OLD LENGTH = 0
 THEREFORE, THE MODULE CANNOT BE USED
 MODULE RUN1 WILL BE GENERATED 07/04/91 15:13:38:27
 LOCATED IN:C:\ASPEN\RUN1
 IN-CORE-PLEX SIZE = 53 RECORDS, WORK SIZE = 51110 INTEGER WORDS

NO ERRORS OR WARNINGS GENERATED
 SIMULATION PROGRAM MAY BE EXECUTED

 * ASPEN PLUS INPUT TRANSLATOR ENDS EXECUTION *

*** CALCULATION TRACE ***

CHEMICAL MANUFACTURERS ASSOC. SIMULATION STUDIES

SIMULATION CALCULATIONS BEGIN

ENTHALPY CALCULATION FOR INLET STREAM 3 OF BLOCK B1
 KODE = 2 NTRIAL = 3 T = 368.1 P = 0.1103E+06 V = 0.0000E+00.

ENTHALPY CALCULATION FOR INLET STREAM 4 OF BLOCK B1
 KODE = 3 NTRIAL = 3 T = 437.7 P = 0.6895E+06 V = 1.000

UOS BLOCK B1 MODEL: RADFRAC

*** ITERATION HISTORY ***

*** OUTSIDE LOOP *** 1 1 1 0.74287E-05

SIMULATION CALCULATIONS COMPLETED

PDF UPDATED

REPORT WRITER ENTERED

REPORT GENERATED

NO ERRORS OR WARNINGS GENERATED

* ASPEN PLUS SIMULATION PROGRAM ENDS EXECUTION *
